Pictorial Atlas of Texas Coastal Hazards

This report is one of a series developed in response to S.R. 268 and H.S.R. 80 which called for the development of model minimum hurricane-resistant building standards for Texas coastal areas by the Texas Coastal and Marine Council. The series includes:

- Report to the 65th Legislature on Building Standards and Coastal Natural Hazards (20 pages).
- Model Minimum Hurricane Resistant Building Standards for the Texas Gulf Coast.
- Potential Wind Damage Reduction Through Use of Wind-Resistant Building Standards.
- Estimated Increased Building Costs Resulting from Use of a Hurricane-Resistant Building Code.
- Photographic Atlas of Texas Coastal Hazards.
- Natural Hazards of the Texas Coastal Zone (prior to S.R. 268, but key technical documentation of hazards).

The above reports can be obtained from:

Texas Coastal and Marine Council
P.O. Box 13407
Austin, Texas 78711
(512/475-5849)

ABOUT THE COUNCIL

The Texas Coastal and Marine Council is a statutory body established by the Legislature for the purpose of assisting in the comprehensive assessment and planning for coastal and marine-related affairs. The Council is a mixed legislative-executive body composed of members independently appointed by the Governor, Lt. Governor, and Speaker. The Council serves in a "brokerage" capacity by bringing together groups with corresponding interests and acting as a catalyst by focusing legislative attention on issues and suggesting remedies which may be implemented by existing line agencies. The basic statutory mission of the Council has been supplemented/focused by Legislative resolutions calling for specific investigations. The Council's members are: *Senator A. R. Schwartz, Chairman; Richard Keith Arnold; Truman G. Blocker, Jr., M.D.; John C. Calhoun, Jr.; Senator Ray Farabee; James J. Flanagan; Senator D. Roy Harrington; Joe B. Harris; Edward H. Harte; Mrs. J. W. Hershey; Representative Joe A. Hubenak; Robert L. Massey; Representative Greg Montoya; Representative Pike Powers; George Fred Rhodes; Charles P. Turco; and Joe C. Moseley II, Executive Director.*

A. R. SCHWARTZ
GALVESTON, BRAZORIA, MATAGORDA, CALHOUN,
ARANSAS AND HARRIS COUNTIES

The Senate of The State of Texas

January 1977

Chairman: TEXAS COASTAL and MARINE COUNCIL

SENATE COMMITTEES:
Chairman: JURISPRUDENCE
Member: ADMINISTRATION
FINANCE

Dear Fellow Texans:

The Texas Gulf Coast is a great place to work, live, and enjoy leisure activities--as attested to by the fact that it is growing faster than Texas as a whole.

Regrettably, this area is plagued with natural hazards that can cause substantial loss of life and property. As a native of Galveston, I am well aware that we were the site of the largest natural disaster in the history of the United States--over 6,000 persons were killed by a single hurricane in 1900. Thanks to improved forecasting and modern communications, we now receive warning of approaching hurricanes. However, according to disaster preparedness experts, a combination of intense coastal development and public and government apathy is occurring that could allow it to happen again.

While the likelihood of a major loss of life may be low, every day I see the consequences of natural processes adversely impacting people's lives and property. During my 25 years in the Legislature, I have worked to make sure that all citizens would be able to purchase windstorm and flood insurance, and to provide for better government action to help prevent disasters and ensure speedy relief and recovery when they do occur.

During the upcoming 65th Legislative Session, I intend to continue this effort, and plan to focus on the following:

- IMPLEMENTATION OF HURRICANE-RESISTANT BUILDING STANDARDS to reduce losses and keep down insurance rates. Special studies done for the Texas Coastal and Marine Council indicate that windstorm losses can be reduced 45-55% for an increased building cost of only 2-3%. For not more than 60-90¢ per square foot on a home that costs $35.00 per square foot, a significant reduction in damage and annual insurance costs would be realized by homeowners.

- ADOPTION OF A SIMPLE NATURAL HAZARDS DISCLOSURE STATEMENT for purchasers of coastal property. Experts agree that awareness and preparation are the keys to survival. I believe that a simple, easy and inexpensive hazards disclosure statement will be a significant step in achieving that goal.

- FULL IMPLEMENTATION OF THE TEXAS DISASTER ACT through provision of adequate funding to the state's Division of Disaster Emergency Services. I co-authored the basic Disaster Act in 1973, and many preventive provisions were specifically included; however, due to both a lack of funding and political reluctance to take many preventive measures, these have not been implemented. I hope to see that changed.

This report, one in a series, uses pictures of past and potential disasters to demonstrate the situations that exist along the Texas Gulf Coast. By developing enough awareness, I hope we can stimulate those actions that will allow people to reside on the coast while minimizing the probable loss to life and property due to natural hazards.

Sincerely,

A. R. Schwartz

A. R. Schwartz

Pictorial Atlas of Texas Coastal Hazards

Prepared by

TEXAS COASTAL AND MARINE COUNCIL

As Partial Response Pursuant to S.R. 268 and H.S.R. 80

January, 1977

PREFACE

Portions of the Texas Coast are disasters waiting to happen. According to recent research, the catastrophe potential due to hurricanes striking coastal areas has increased dramatically. The growing amount of coastal development, the natural hazards of subsidence and erosion, the disregard for natural protective elements on the coast, plus poor locational decisions and construction practices, are all causes of this increased catastrophe potential. On the Texas coast, population in the 18 counties bordering the Gulf increased between 2.5-3.0% per year between 1960 and 1970 as compared with an approximate increase of 1.5-2.0% per year for the nation as a whole. All indications are that this population trend will continue for the Texas coast.

Number of hurricane landfalls, 1900-1972	27
Area (square miles) of salt-water flooding, Hurricanes *Carla* and *Beulah*	3,164
Area (square miles) of fresh-water flooding, Hurricane *Beulah*	2,187
Area (square miles) of fresh-water flooding by hurricane rainfall (floodplains), northern part of Coastal Zone only	2,073
Area (square miles) below elevation of 20 feet (MSL): subject to salt-water flooding by tidal surge	5,787
Number of active or potential hurricane washover channels	137
Number of miles of Gulf beach erosion: greater than 10 feet per year (long term)	47
Number of miles of Gulf beach erosion: from 5 to 10 feet per year (long term)	50
Number of miles of Gulf beach erosion: from 0 to 5 feet per year (long term)	104
Number of miles of bay and lagoon shoreline erosion	408
Area (square miles) of land subsidence: greater than 5 feet	227
Area (square miles) of land subsidence: from 1 to 5 feet	1,080
Area (square miles) of land subsidence: from 0.2 to 1 foot	5,422
Number of miles of known active surface faults	96
Number of miles of Gulf shoreline	367
Number of miles of bay-lagoon shoreline	1,100
Area (square miles) of bays and lagoons	2,075
Area (square miles) of land in map area	18,000

The Texas Gulf coast, with its mild climate and many other natural and economic amenities, is a good place to live and spend one's leisure time. Unfortunately, nature has also provided some natural phenomena which present hazards to life and property. It is possible, through careful planning and preparation, including education, to significantly reduce the risks presented by these hazards.

Many residents of the Texas coast have never experienced the full force of a major hurricane. The last major hurricane to strike the upper Texas coast was Carla in 1961. Thus, no upper coast resident not yet out of high school has felt the force of a major hurricane. The last significant hurricane to strike any part of the Texas coast was Celia in 1970. Since the Texas coast has averaged one hurricane every 2.5 years, coastal residents are long overdue for one.

Land surface subsidence due to the withdrawal of ground water has lowered the land elevation up to 8 feet in some places around Galveston Bay; altogether more than 1300 square miles on the Texas coast are subsiding at rates up to 5 feet per year. These lowered elevations greatly increase the flooding threat of even a small storm, and in one case have caused the abandonment of numerous homes. Equally startling is the fact that subsidence is now reducing road elevations of evacuation routes of coastal communities, including I-45 and the approaches to the Galveston causeway, which is the principal escape route for that portion of the island's some 74,000 residents who opt to evacuate. Tides of 5 feet will inundate many critical evacuation routes.

Erosion, though not a threat to human life, does result in the significant loss of property. Currently, severe erosion (greater than 10 feet per year) is occurring on 42 percent or 153 miles of the coast and another 28 percent is experiencing moderate erosion. Accretion is occurring over 13 percent of the gulf shore and another 17 percent is in equilibrium.

This publication is an attempt to bring to the public's attention examples of existing natural processes and the potential disaster situations they pose to the Texas coast. Only with increased public awareness and consequent preventive-preparedness actions can the growing threat to life and property due to hurricanes and other natural processes be dealt with and future losses minimized. In order to further increase general awareness of these potentially destructive processes, this document uses pictures to show damage and possible circumstances which lead to future losses. While this brief report relies on pictures to deliver its message, there is a very substantial body of scientific and technical data that thoroughly documents, in an accepted scientific manner, the nature, extent, and location of these natural hazards along the Texas coast. The best single document which discusses and maps the hazards is the Natural Hazards Atlas of the Texas Gulf Coast. See References for this and other materials.

IT CAN HAPPEN. THE LA RICHELIEU APARTMENTS IN PASS CHRISTIAN, MISSISSIPPI, WERE EXPENSIVE WELL-BUILT BRICK APARTMENTS LOCATED BEHIND A SEAWALL AND ACROSS A ROAD-WAY FROM THE GULF OF MEXICO. HURRICANE CAMILLE STRUCK THE MISSISSIPPI COAST IN 1969 WITH 200-MILE PER HOUR WINDS AND A 25-FOOT SURGE TIDE. THE APARTMENTS WERE COM-PLETELY DEMOLISHED AND OF THE TWO DOZEN RESIDENTS WHO STAYED TO HAVE A HURRICANE PARTY, ONLY ONE SURVIVED AFTER DRIFTING 12 HOURS IN HURRICANE FLOODS.

MAJOR STRUCTURES ALONG THE TEXAS COAST ARE NO MORE IMMUNE TO DESTRUCTION IN THE EVENT OF AN EXTREME HURRI-CANE. LESSER STRUCTURES ARE APT TO FAIL EVEN SOONER.

THE ADVANTAGES OF COASTAL LIVING ARE MANY, BUT PAST EXPERIENCE INDICATES THAT COASTAL RESIDENTS NEED TO ASSUME THE RISK AND RESPONSIBILITY OF PREPARING FOR AND GETTING OUT OF THE WAY OF HURRICANES.

PHOTO A—LA RICHELIEU APARTMENTS, PASS CHRISTIAN, MISSIS-SIPPI BEFORE HURRICANE CAMILLE.

PHOTO B—REMAINS OF LA RICHELIEU APARTMENTS AFTER HURRI-CANE CAMILLE IN 1969.

PHOTO A

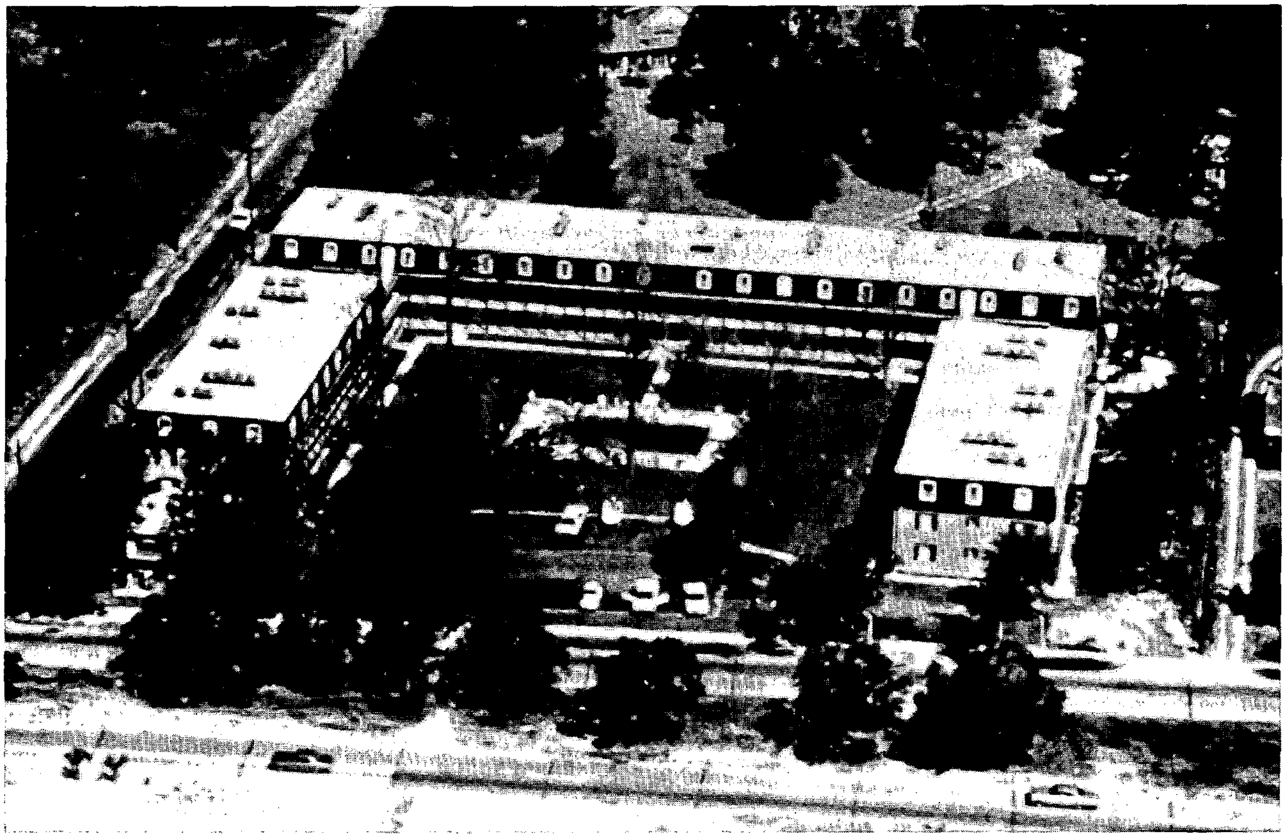


PHOTO B

WIND IS SOMETIMES THE PRINCIPAL DAMAGE MECHANISM. HURRICANE CELIA, WHICH STRUCK THE TEXAS COAST NEAR CORPUS CHRISTI IN 1970, CAUSED MOST OF HER DAMAGE THROUGH SUSTAINED WINDS OF 130 M.P.H. AND GUSTS ESTIMATED TO BE 160–180 M.P.H. DAMAGE FROM HURRICANE WINDS IS NOT ONLY SUSTAINED NEAR THE WATER, BUT ALSO WELL INLAND. FOR EXAMPLE, THE TOWNS OF GREGORY AND PORTLAND APPROXIMATELY 20 MILES FROM THE GULF WERE VIRTUALLY DESTROYED BY CELIA'S WINDS. EAGLE PASS, ALMOST 200 MILES INLAND, WAS LASHED BY 90 M.P.H. WINDS.

PHOTO A—HOUSING DEVELOPMENT, PORT ARANSAS, AFTER HURRICANE CELIA.

PHOTO B—TOWN OF ARANSAS PASS AFTER HURRICANE CELIA.

PHOTO A

PHOTO B

HIGH RISE STRUCTURES IF PROPERLY BUILT CAN BE EXPECTED TO SURVIVE ANY BUT THE MOST EXTREME HURRICANE; HOWEVER, SIGNIFICANT DAMAGE MAY BE SUFFERED ON WALL COVERINGS, WINDOWS, PORCHES, ETC. UNFORTUNATELY, ONCE A STRUCTURE IS COMPLETED, IT IS OFTEN VERY DIFFICULT TO PRECISELY DETERMINE ITS STRENGTH. EVEN IF THE BUILDING IS WELL-DESIGNED AND ENGINEERED, OVERSIGHTS IN CONSTRUCTION AND FAILURE TO INSURE PROPER INSPECTION MAY RESULT IN A STRUCTURE THAT WILL FAIL BELOW ITS DESIGN STRENGTH.

IN THE FUTURE, AS POPULATION INCREASES ON THE BARRIER ISLANDS AND OTHER EXPOSED AREAS, IT MAY BECOME IMPOSSIBLE TO EVACUATE RESIDENTS. IT WOULD THEN BE NECESSARY TO USE "VERTICAL EVACUATION." THIS INVOLVES RELOCATING PEOPLE IN THE INTERIOR SPACE OF HIGH-RISE BUILDINGS. IT BECOMES VITAL TO KNOW HOW STRONG BUILDINGS ARE IF THIS EVER OCCURS.

PHOTO A—DAMAGE DONE TO LARGE BUILDING IN PANAMA CITY, FLORIDA, BY HURRICANE ELOISE, 1975.
PHOTO B—SIMILAR STRUCTURE LOCATED ON THE TEXAS COAST FACING THE GULF.

PHOTO A

PHOTO B

SEVERE SUBSIDENCE DUE PRINCIPALLY TO GROUNDWATER PUMPING IS OCCURRING ON PARTS OF THE TEXAS COAST. IN ONE AREA NEAR THE SAN JACINTO MONUMENT, THE LAND HAS SUNK MORE THAN EIGHT FEET. WHILE SUCH EXTREME SUBSIDENCE IS LOCALIZED, THE "DISHPAN" EFFECT SPREADS OUT MORE THAN 100 MILES FROM ITS CENTER ON THE UPPER COAST, AND THE AREA OF FIVE FEET OR MORE SUBSIDENCE CAN BE FELT AS FAR AS 100 MILES FROM THE CENTER. THE FOLLOWING AREAS HAVE BEEN IMPACTED BY SUBSIDENCE:

GREATER THAN 5 FEET—227 SQUARE MILES
FROM 1 TO 5 FEET—1,080 SQUARE MILES
FROM 0.2 TO 1.0 FEET—5,422 SQUARE MILES

PREVIOUSLY IT WAS THOUGHT THAT THE WHOLE AREA WAS SINKING UNIFORMLY, BUT RECENT INVESTIGATIONS INDICATE THAT THE SUBSIDENCE IS EFFECTED BY FAULTS WHICH MAY ACT AS HYDROLOGICAL BARRIERS AND EXAGGERATE CONDITIONS IN A PARTICULAR LOCATION. THE ACTIVATION OF FAULTS IS A PROBLEM IN ITSELF, BECAUSE IT CAN DAMAGE ROADS, BUILDING, UTILITY, ETC. THAT CROSS THEM.

SUBSIDENCE MAKES COASTAL RESIDENCES MUCH MORE SUSCEPTIBLE TO ORDINARY FLOODING AND IN SOME CASES, HOMES, SUCH AS THIS ONE NEAR BAYTOWN, HAVE BEEN PERMANENTLY SURROUNDED BY WATER. SUBSIDENCE ALSO GREATLY INCREASES VULNERABILITY TO HURRICANE FLOODING AND CONSEQUENT LOSS OF LIVES AND PROPERTY.

PHOTO A—ABANDONED HOUSE IN BROWNWOOD SUBDIVISION NEAR BAYTOWN.

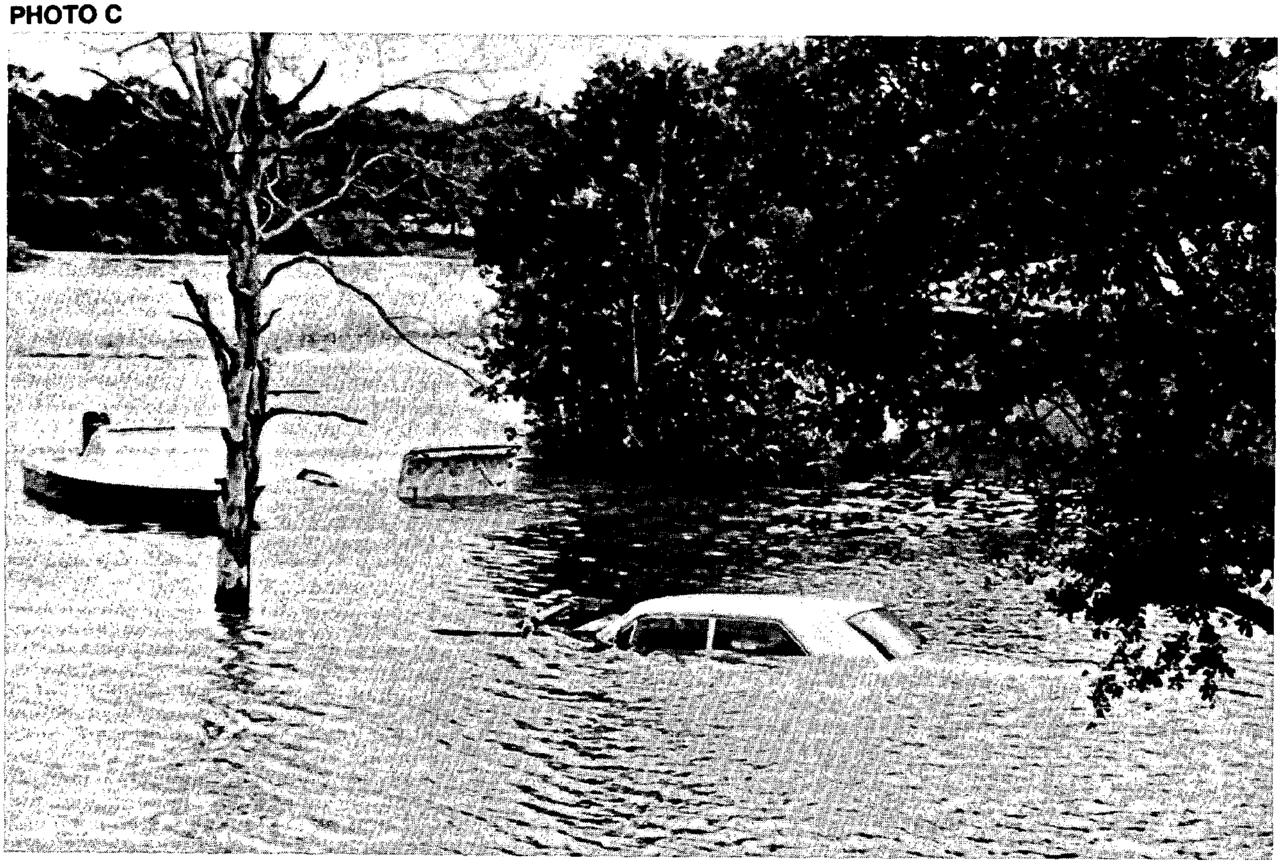
PHOTO B—DOWNTOWN STREET IN BAYTOWN AFTER TROPICAL STORM DELIA, 1973.

PHOTO C—CARS SUBMERGED IN BAYTOWN AFTER TROPICAL STORM DELIA.

PHOTO A

PHOTO B

PHOTO C



SOME OF THE MOST BEAUTIFUL BEACHES IN TEXAS AND A SUBTROPICAL CLIMATE ARE FOUND OFF SOUTH PADRE ISLAND. THESE AMENITIES, COMBINED WITH ITS PROXIMITY TO MEXICO, MAKE SOUTH PADRE ISLAND GREAT FOR RETIREMENT HOMES AND VACATION FACILITIES. BECAUSE OF ITS ATTRACTIVENESS, SOUTH PADRE HAS EXPERIENCED MAJOR GROWTH IN THE LAST DECADE.

MANY OF THE SAME ELEMENTS WHICH MAKE SOUTH PADRE AN INVITING PLACE TO LIVE OR VISIT ALSO MAKE IT SUSCEPTIBLE TO DAMAGE FROM NATURAL PROCESSES AND PHENOMENA. LIKE OTHER TEXAS BARRIER ISLANDS, IT CAN BE COMPLETELY INUNDATED BY A MAJOR HURRICANE. LOW ACCESS ROADS CAN FLOOD EARLY AND THUS BLOCK EVACUATION. HURRICANE BEULAH, 1967, CUT PADRE ISLAND IN MORE THAN 50 PLACES AND THESE WASHOVER CHANNELS, IF REOPENED, CAN DESTROY STRUCTURES BUILT IN THEM. ALSO MUCH OF THE GULF SHORELINE IS ERODING.

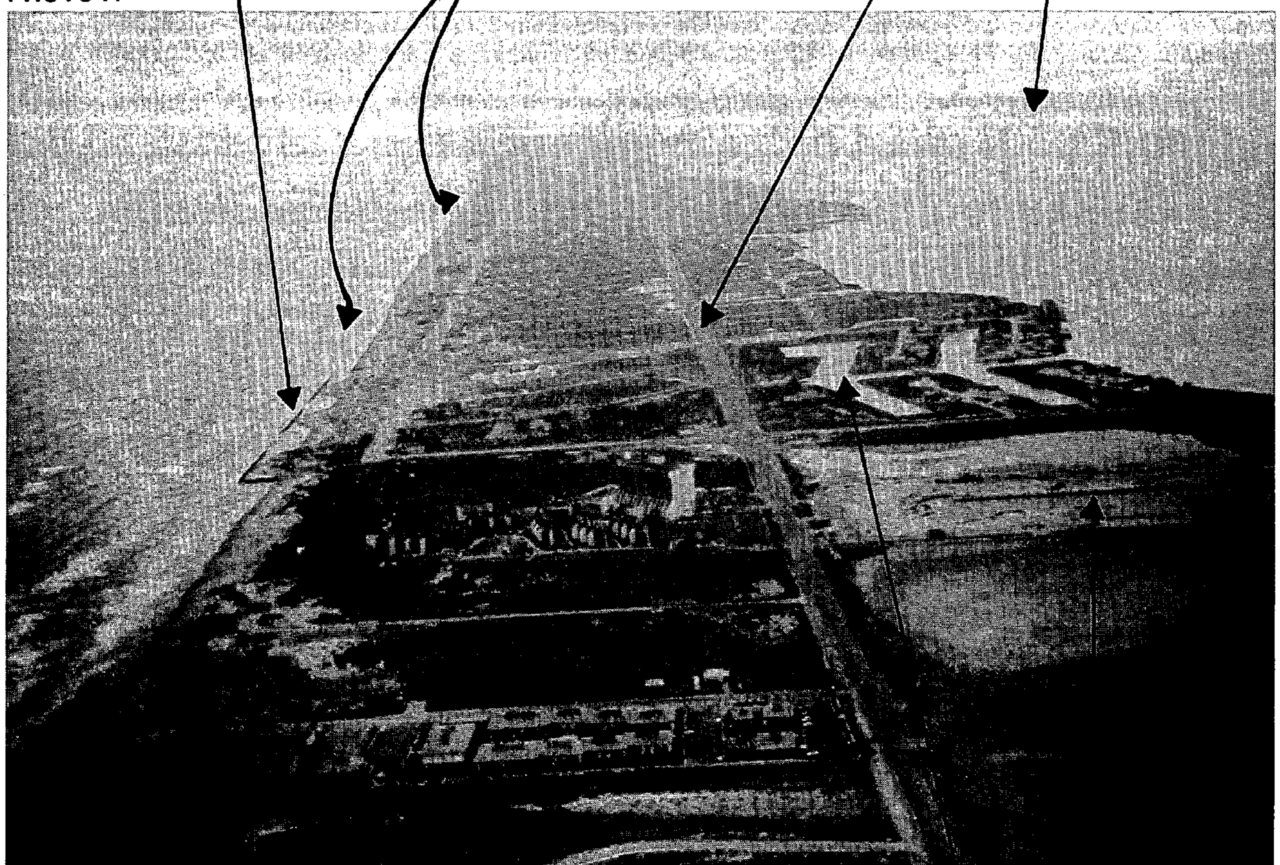
PHOTO—SOUTH PADRE ISLAND LOOKING SOUTH WITH NATURAL HAZARDS INDICATED

EROSION, IN EXCESS OF 10 FEET PER YEAR IS ENCROACHING UPON PRIVATE PROPERTY AND DESTROYING THE PUBLIC BEACH. THIS SEAWALL, NOW WELL OUT IN THE SURF, WAS BUILT IN 1962.

LOW ELEVATION ROADS AND BRIDGE APPROACHES CAN BE CUT EARLY BY RISING TIDES FAR IN ADVANCE OF HURRICANES. ALSO NOTE THAT THERE IS ONLY ONE EVACUATION ROUTE OFF SOUTH PADRE ISLAND.

THE LEVELING OF DUNES FOR BEACHFRONT CONSTRUCTION CAN ELIMINATE THE NATURAL PROTECTION AGAINST STORM SURGE.

PHOTO A



CONSTRUCTION IN WASH-OVER CHANNELS.

CONSTRUCTION OF CHANNELS PART-WAY THROUGH THE ISLAND CAN MAKE IT MORE SUSCEPTIBLE TO SEVERING BY WASHOVERS.

SEVERE LOCAL EROSION CAN BE CAUSED BY MINOR HURRICANES WITH MINIMAL WINDS AND MODERATE STORM SURGE AND THIS MAY PRESENT A HAZARD TO BEACH FRONT PROPERTY. HURRICANE DAMAGE DUE TO EROSION CAN BE GREATLY REDUCED, HOWEVER, THROUGH THE USE OF WISE BUILDING TECHNIQUES. FOR EXAMPLE, A SLAB FOUNDATION IS MUCH MORE SUSCEPTIBLE TO SEVERE DAMAGE FROM HURRICANE EROSION THAN A STRUCTURE BUILT ON PILINGS AND PROPERLY ANCHORED.

PHOTO A

PHOTO B

PHOTO A—PANAMA CITY, FLORIDA, MOTEL AFTER HURRICANE ELOISE, 1975.

PHOTO B—SOUTH PADRE ISLAND MOTEL, 1976.

PHOTO C—BRICK HOUSE ON SLAB FOUNDATION AFTER HURRICANE BEULAH—A TOTAL LOSS.

PHOTO D—BEACH FRONT HOUSE ON PILE FOUNDATION AFTER HURRICANE BEULAH—NO MAJOR STRUCTURAL DAMAGE.

PHOTO C

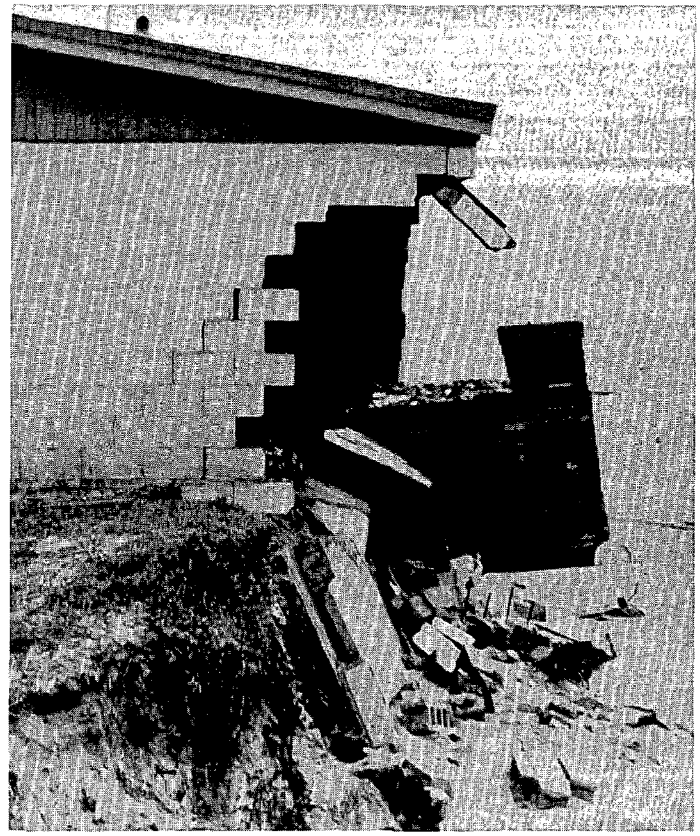


PHOTO D

CHRONIC EROSION PLAGUES MUCH OF SOUTHERN SOUTH PADRE ISLAND WHICH IS ERODING 5-10 FEET PER YEAR. THE PRIVATE SEAWALL SHOWN ON THE OPPOSITE PAGE WAS CONSTRUCTED IN 1962 AND WAS ORIGINALLY 200 FEET FROM THE HIGH TIDE LINE. THIS SEAWALL WAS INTENDED AS A REPLACEMENT FOR ANOTHER SEAWALL 20 FEET OUT THAT WAS PREVIOUSLY DESTROYED BY A STORM PRIOR TO 1962. WHILE HURRICANE BEULAH IN 1967 DID ACCELERATE SOME LOCALIZED EROSION, THE BEACH IN THIS AREA HAS BEEN RECEDING MORE THAN 10 FEET PER YEAR.

A SEAWALL SUCH AS THIS WOULD COST APPROXIMATELY $100/LINEAR FOOT TODAY. A MAJOR SEAWALL SUCH AS THE GALVESTON SEAWALL WOULD CURRENTLY COST BETWEEN $1200-1500/LINEAR FOOT. THE SMALL WALLS BEING BUILT ON THE BEACH SIDE OF STRUCTURES ARE USED PRINCIPALLY TO RETAIN THE FILL MATERIAL BEHIND THEM AND THEIR EFFECTIVENESS AGAINST ANY HURRICANE IS NEGLIGIBLE.

EVEN IF SUCH SEAWALLS DO NOT FAIL STRUCTURALLY, EROSION CAN REMOVE THE SAND IN FRONT OF THE WALL AND THUS CAUSE A LOSS OF A MAJOR AMENITY—THE BEACH.

PHOTO A—PRIVATE SEAWALL ON SOUTH PADRE ISLAND LOOKING NORTH.

PHOTO B—SAME PRIVATE SEAWALL LOOKING SOUTH.

PHOTO A

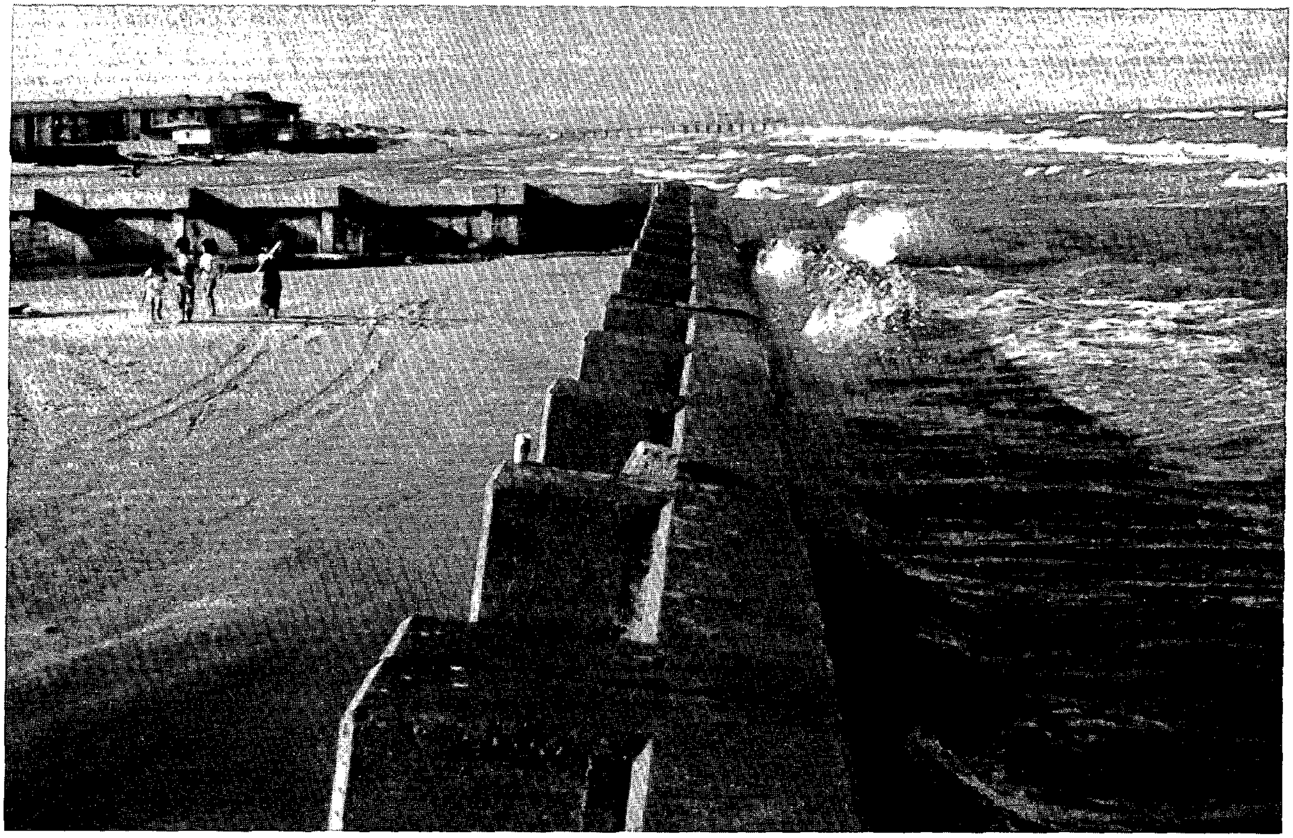
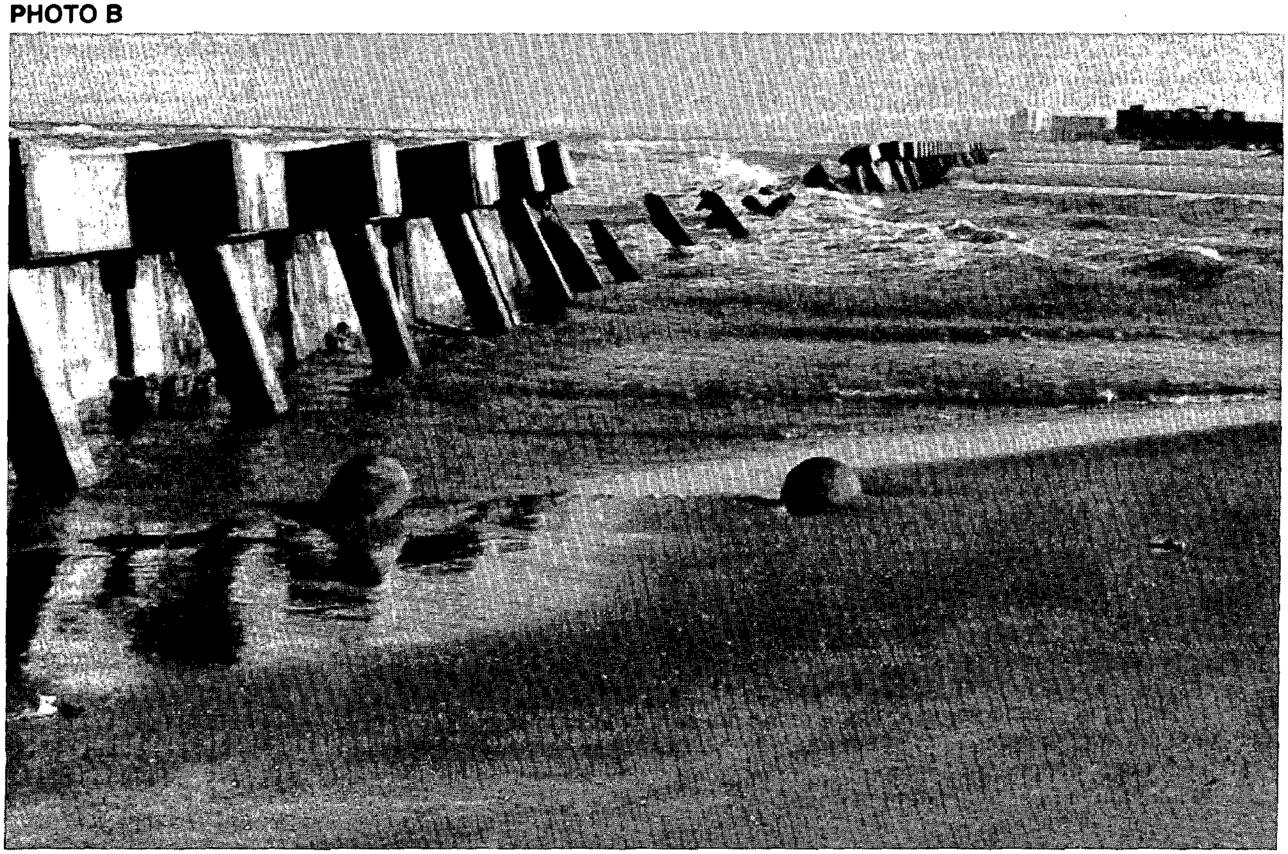


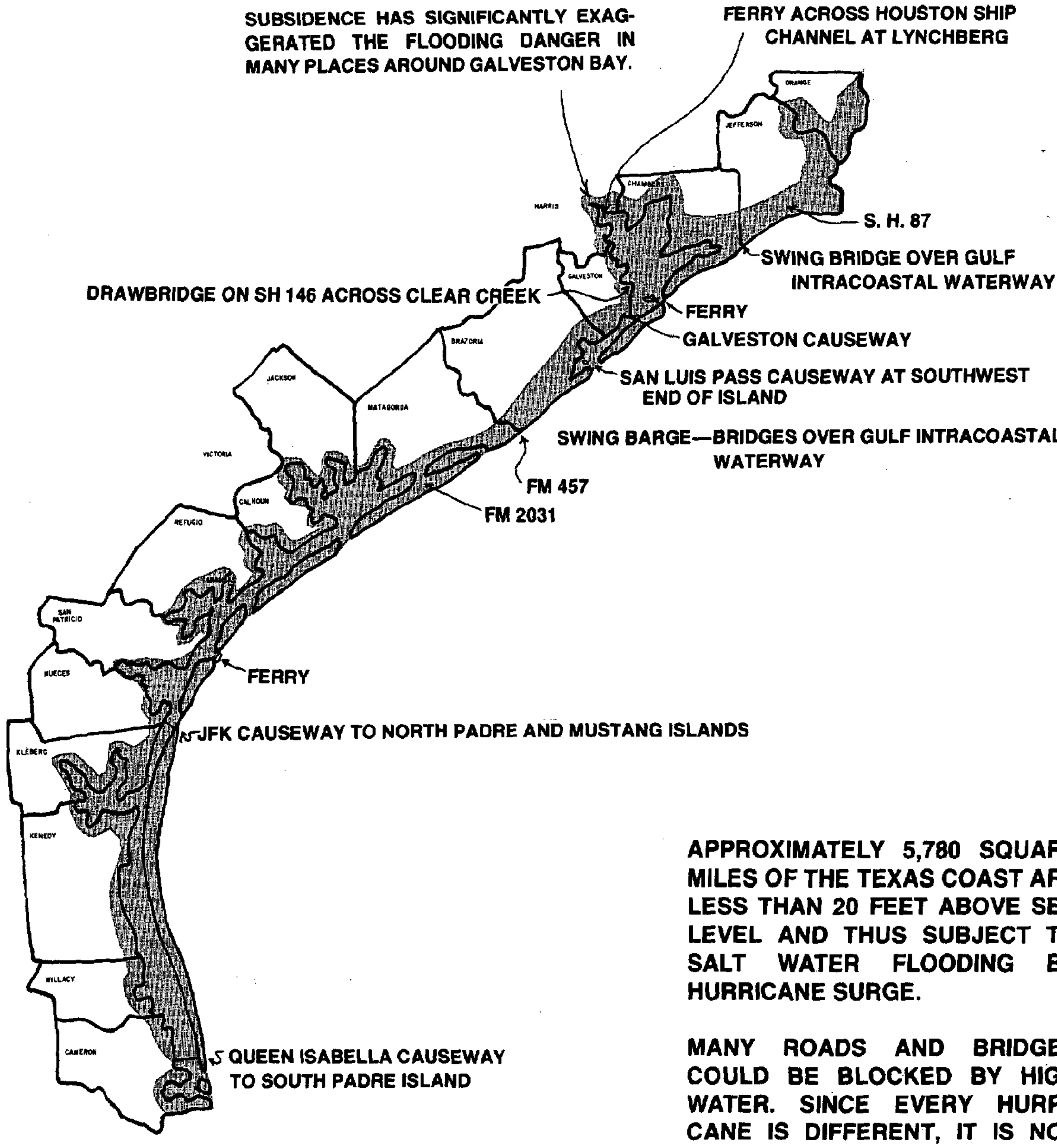
PHOTO B



EVACUATION FROM TEXAS' BARRIER ISLANDS, PENINSULAS, AND OTHER LOW-LYING COASTAL AREAS PRESENTS A CRITICAL PROBLEM IMMEDIATELY PRIOR TO A HURRICANE. CAUSEWAYS, DRAWBRIDGES, AND FERRIES REPRESENT THE ONLY MEANS OF ESCAPE FOR RESIDENTS IN MANY OF THESE AREAS. ALL OF THE ABOVE MEANS OF EVACUATION COULD BE CUT OFF PRIOR TO A HURRICANE AS EXPLAINED BY THE PHOTOS AND TEXTS ON THE FOLLOWING PAGES.

HURRICANE FORECASTING HAS GREATLY IMPROVED IN RECENT YEARS. EXPERTS NOW GENERALLY AGREE THAT FORECASTING CAPABILITY HAS REACHED A PLATEAU AND SIGNIFICANT IMPROVEMENTS ARE NOT ANTICIPATED IN THE NEAR FUTURE. HURRICANE FORECASTING INVOLVES EXTENSIVE MONITORING AND COMPLEX MODELLING OF A NATURAL PHENOMENON WHICH DISPLAYS SIGNIFICANT RANDOM BEHAVIOR. PREDICTIONS MUST BE MADE OF THE HURRICANE PATH, LANDFALL POINT, THE INTENSITY, AND THE SPEED OF TRAVEL.

MAP—SOME CRITICAL ACCESS/EVACUATION POINTS ALONG THE TEXAS COAST
(Prepared in cooperation with the Division of Disaster Emergency Services)



SOME CRITICAL EVACUATION POINTS ALONG THE TEXAS COAST

APPROXIMATELY 5,780 SQUARE MILES OF THE TEXAS COAST ARE LESS THAN 20 FEET ABOVE SEA LEVEL AND THUS SUBJECT TO SALT WATER FLOODING BY HURRICANE SURGE.

MANY ROADS AND BRIDGES COULD BE BLOCKED BY HIGH WATER. SINCE EVERY HURRICANE IS DIFFERENT, IT IS NOT POSSIBLE TO PRESCRIBE EVACUATION ROUTES FAR IN ADVANCE. WHEN A HURRICANE THREATENS, KEEP YOUR RADIO ON TO HEAR THE LATEST SITUATIONS AND EVACUATION INSTRUCTIONS.

MANY SMALL ROADS LEADING FROM PARTICULAR SUBDIVISIONS AND BETWEEN MAJOR ARTERIES CONTAIN CRITICAL POINTS AT LOW PLACES, CULVERTS, AND SMALL BRIDGES.

CAUSEWAYS ARE THE PRINCIPAL MEANS OF EGRESS FROM THE HEAVILY POPULATED ISLANDS. ALTHOUGH THE CAUSEWAYS THEMSELVES ARE ABOVE STORM SURGES, THE LAND APPROACHES TO THEM ARE ONLY A FEW FEET ABOVE MEAN SEA LEVEL. THE APPROACH TO THE GALVESTON CAUSEWAY VIA INTERSTATE 45 IS ALSO PLAGUED BY SUBSIDENCE.

COMPOUNDING THE EVACUATION PROBLEM IS THE INCREASING POPULATION ON THE ISLANDS. ACCORDING TO THE NATIONAL HURRICANE CENTER, 500 VEHICLES/TRAFFIC LANE/HOUR CAN THEORETICALLY EVACUATE. HOWEVER, IN PRACTICE, ONLY ABOUT 350 VEHICLES/LANE/HOUR CAN SUCCESSFULLY MOVE OVER ROADS. THUS, ON THREE LANES OF OUTBOUND TRAFFIC, APPROXIMATELY 1000/VEHICLES/HOUR CAN BE MOVED IF ALL GOES WELL. WITH A TWELVE HOUR WARNING BEFORE LANDFALL, 12,000 VEHICLES COULD BE EVACUATED. HOWEVER, THE STORM SURGE COULD CUT CAUSEWAY APPROACHES AT LEAST 4–6 HOURS PRIOR TO LANDFALL, LEAVING ONLY 6–8 HOURS IN WHICH TO EVACUATE ALL THOSE LEAVING. PERSONS TRAPPED IN CARS ON LOW-LYING ROADS WOULD NOT HAVE VERY GOOD ODDS OF SURVIVING.

PHOTO A—GALVESTON CAUSEWAY CONNECTING GALVESTON ISLAND TO THE MAINLAND.

PHOTO B—JFK CAUSEWAY LINKING CORPUS CHRISTI TO PADRE ISLAND.

PHOTO C—QUEEN ISABELLA CAUSEWAY, THE STATE'S LONGEST BRIDGE, LINKING MAINLAND PORT ISABEL TO SOUTH PADRE ISLAND.

PHOTO A

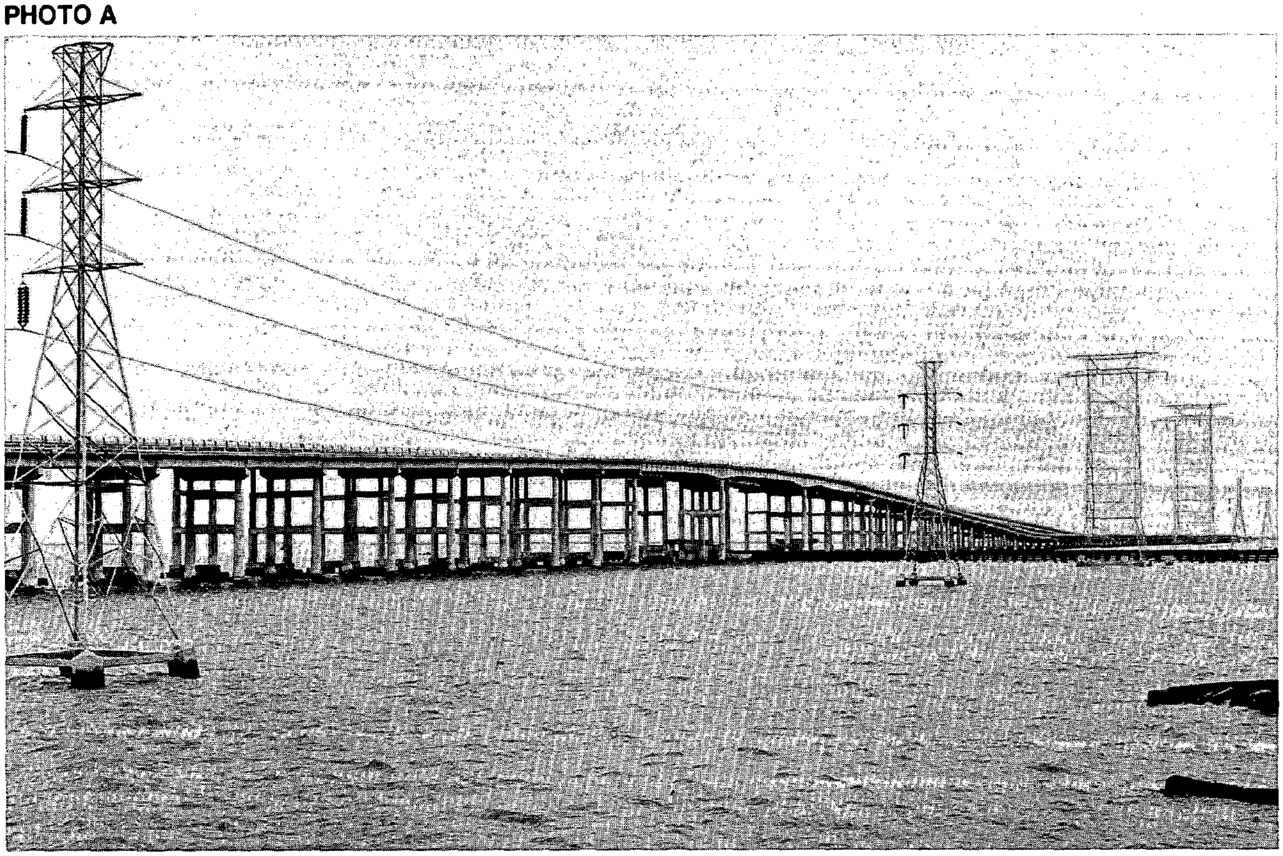


PHOTO B

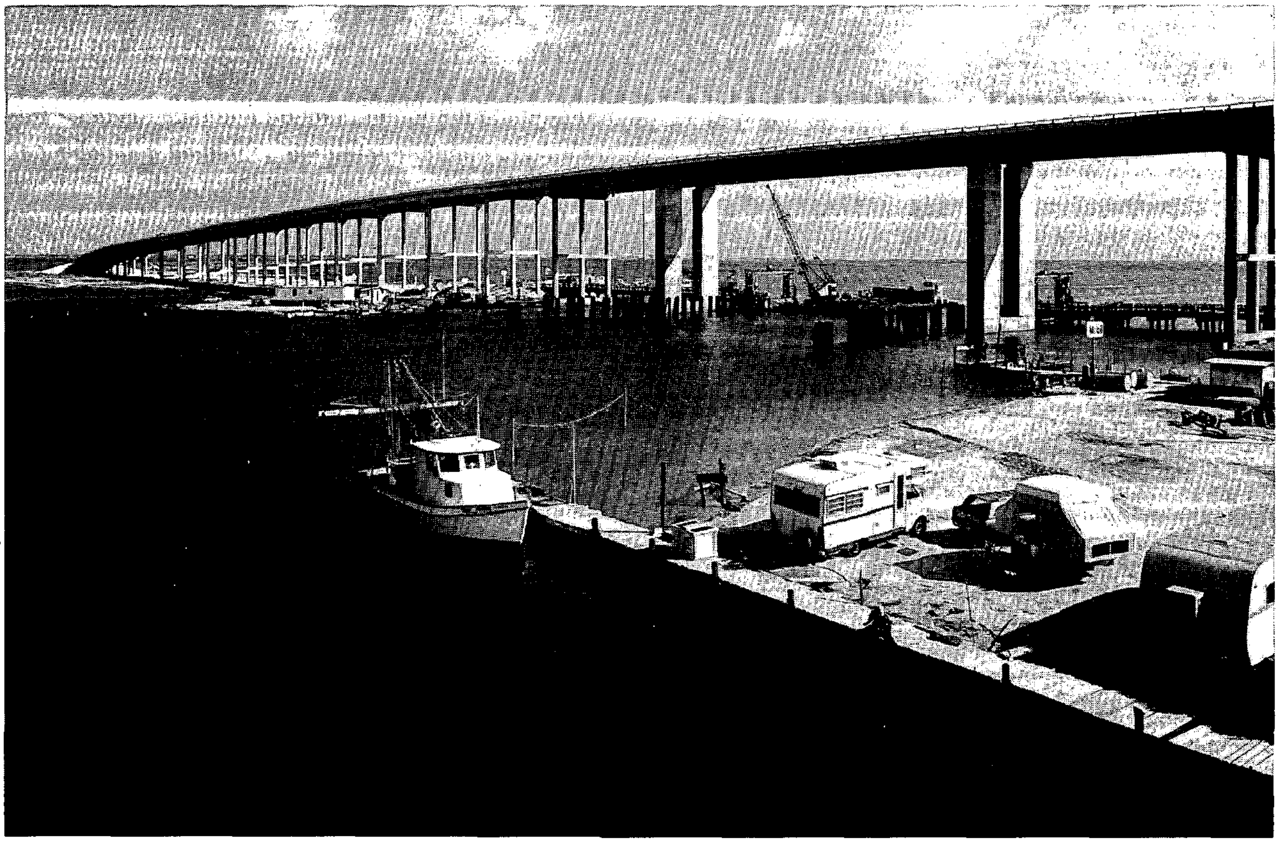
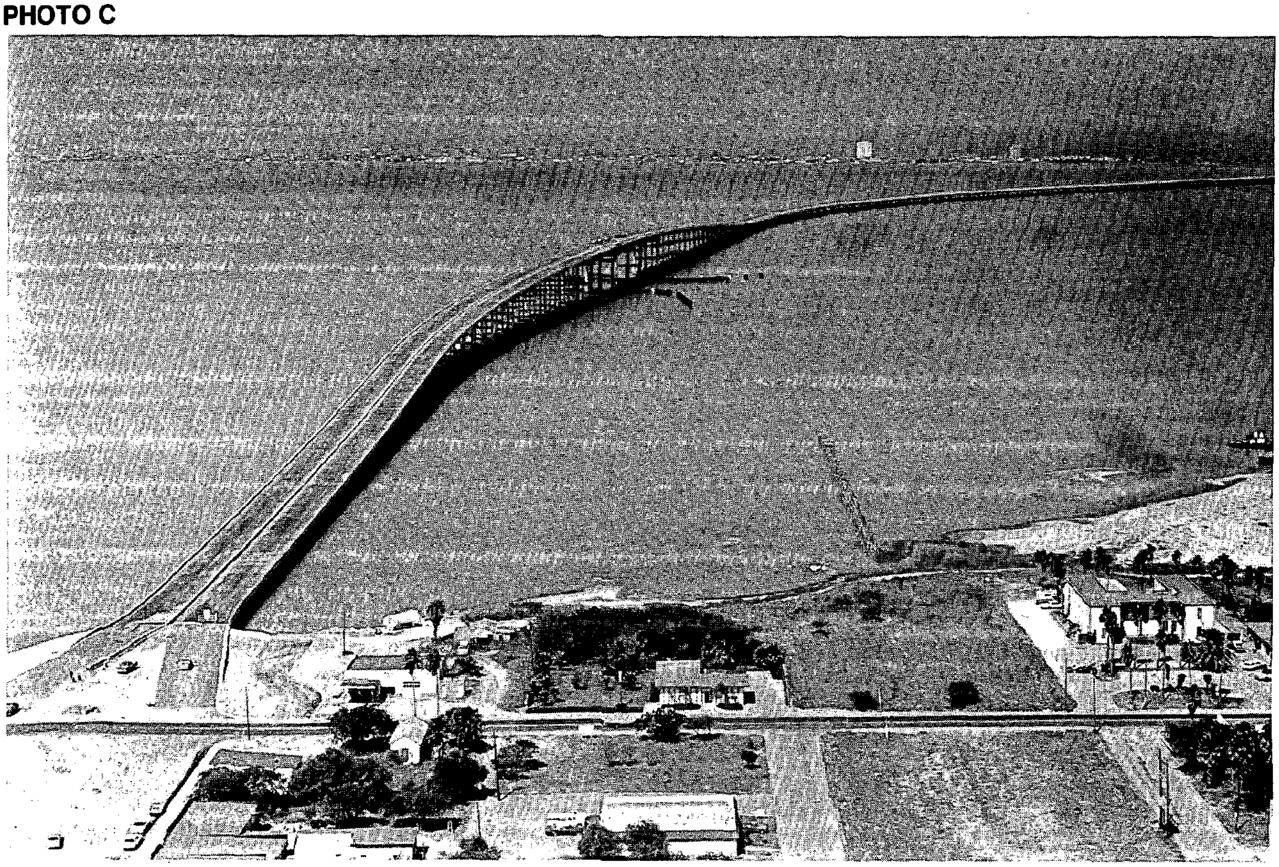


PHOTO C



LOW ELEVATIONS AND FLAT TOPOGRAPHY OF THE TEXAS COAST CREATE HAZARDOUS SITUATIONS BY INCREASING THE AREA'S SUSCEPTIBILITY TO HURRICANE FLOODING. LARGE RESIDENTIAL DEVELOPMENTS ARE OFTEN BUILT ON LOW-LYING FILLED LAND TO PROVIDE EASY ACCESS TO BOAT CHANNELS. IN MANY PLACES THERE IS SIMPLY NO "HIGH" GROUND (i.e., GREATER THAN 15–20 FEET MEAN SEA LEVEL) NEAR WATER.

IN SOME CASES, THE ONLY ROAD WHICH PROVIDES A MEANS OF EGRESS CAN EASILY BE CUT BY RISING WATER. SOMETIMES IT PARALLELS THE BEACH OR A BAY SHORELINE, AND IN OTHER INSTANCES IT MAY CROSS A CREEK OR BAYOU ON A LOW BRIDGE.

PHOTO A—RESIDENTIAL DEVELOPMENT ON MAN-MADE LAND IN ARANSAS COUNTY.

PHOTO B—STATE HIGHWAY 87 BETWEEN THE TOWNS OF PORT BOLIVAR AND SABINE PASS.

PHOTO A

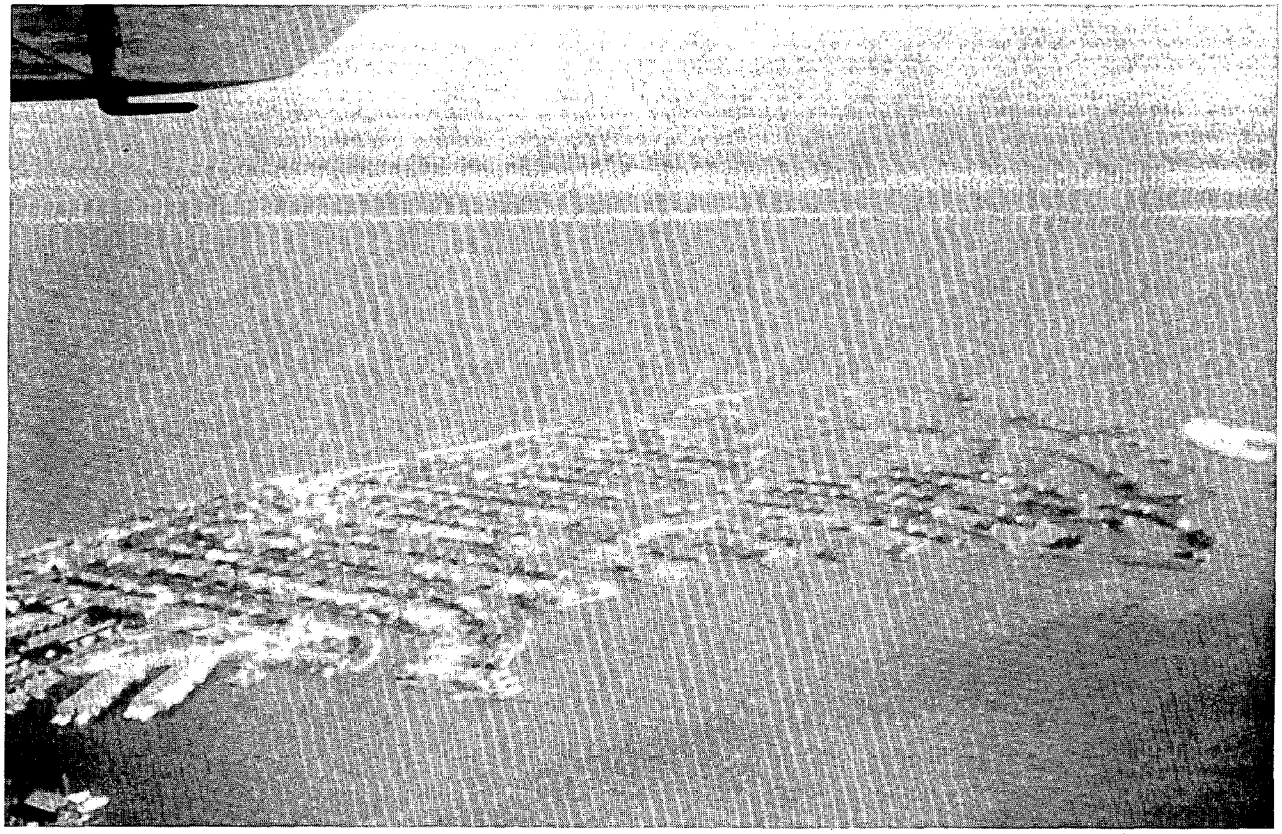
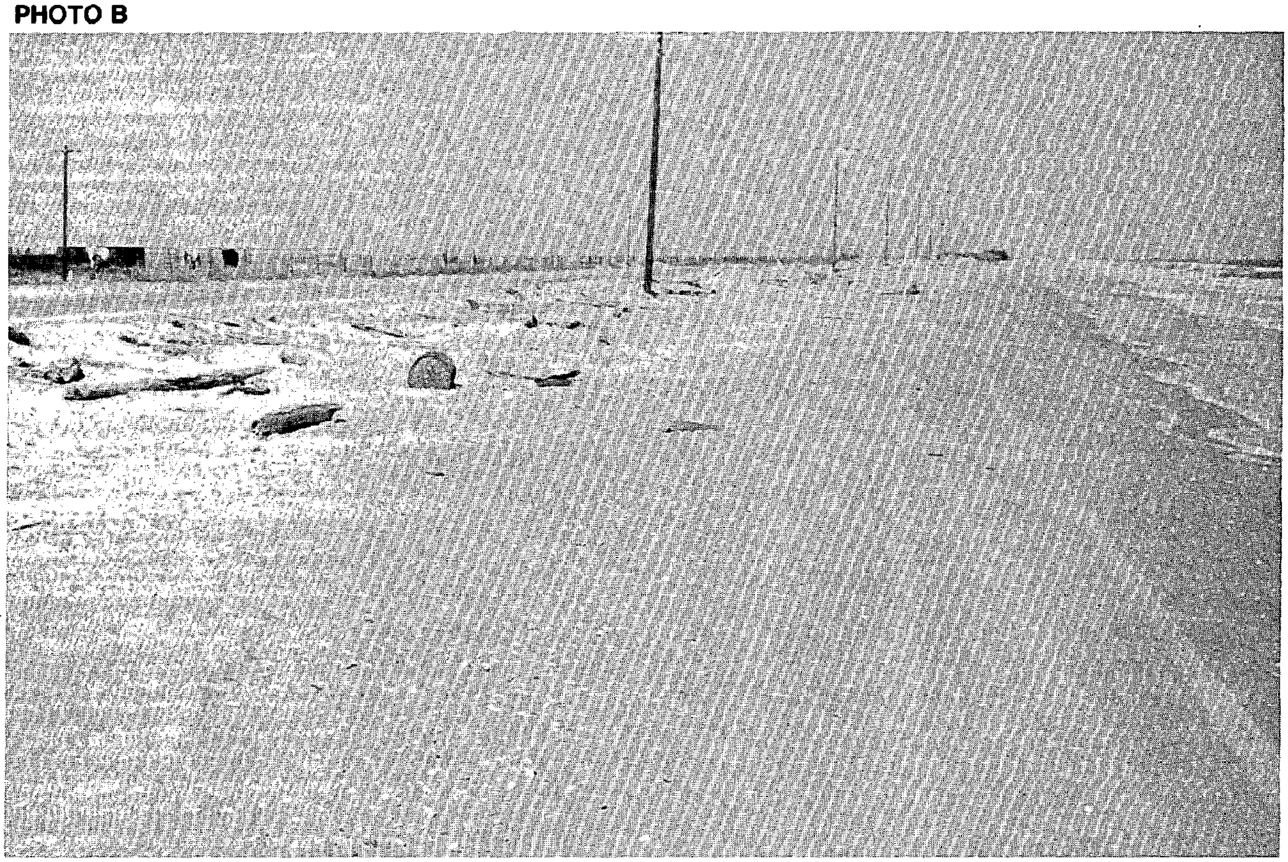


PHOTO B



DRAWBRIDGES ARE STILL USED IN A FEW PLACES ALTHOUGH THE MAJOR POPULATION CENTERS LOCATED ON TEXAS ISLANDS AND PENINSULAS ARE CONNECTED BY CAUSEWAYS TO THE MAINLAND. IN ADDITION, A MAJOR DRAWBRIDGE IS LOCATED ON THE MAINLAND OVER CLEAR CREEK BETWEEN KEMAH AND SEABROOK. DRAWBRIDGES CAN BECOME DANGEROUS BOTTLENECKS DURING EVACUATION SINCE FEDERAL LAW REQUIRES THAT IF BOTH VESSELS AND VEHICLES ARRIVE AT THE DRAWBRIDGE, THE VESSELS WILL HAVE PRIORITY.

PHOTO A—REVOLVING BRIDGE OVER THE INTRACOASTAL WATERWAY AT HIGH ISLAND, TEXAS (NOW BEING REPLACED WITH HIGH BRIDGE BY DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION).

PHOTO B—APPROACH TO DRAWBRIDGE ON STATE HIGHWAY 146 OVER CLEAR CREEK.

PHOTO A

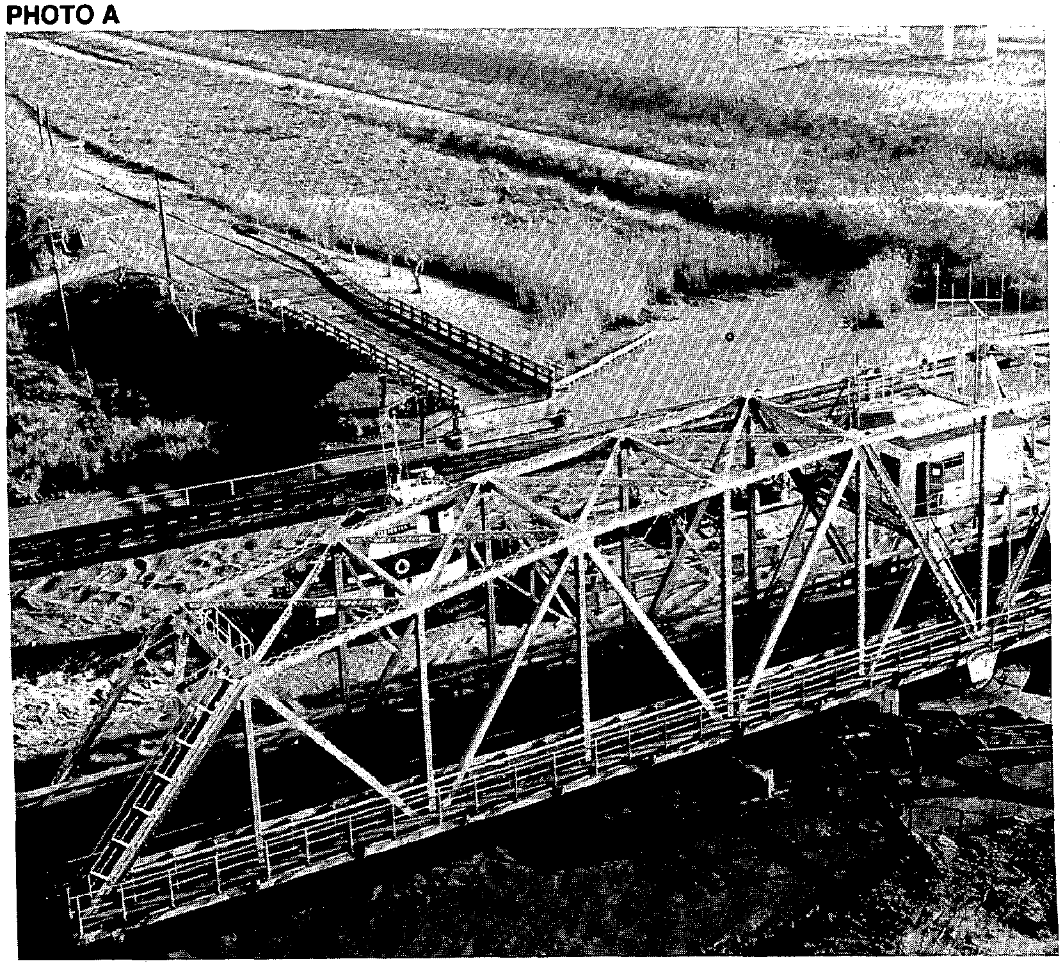
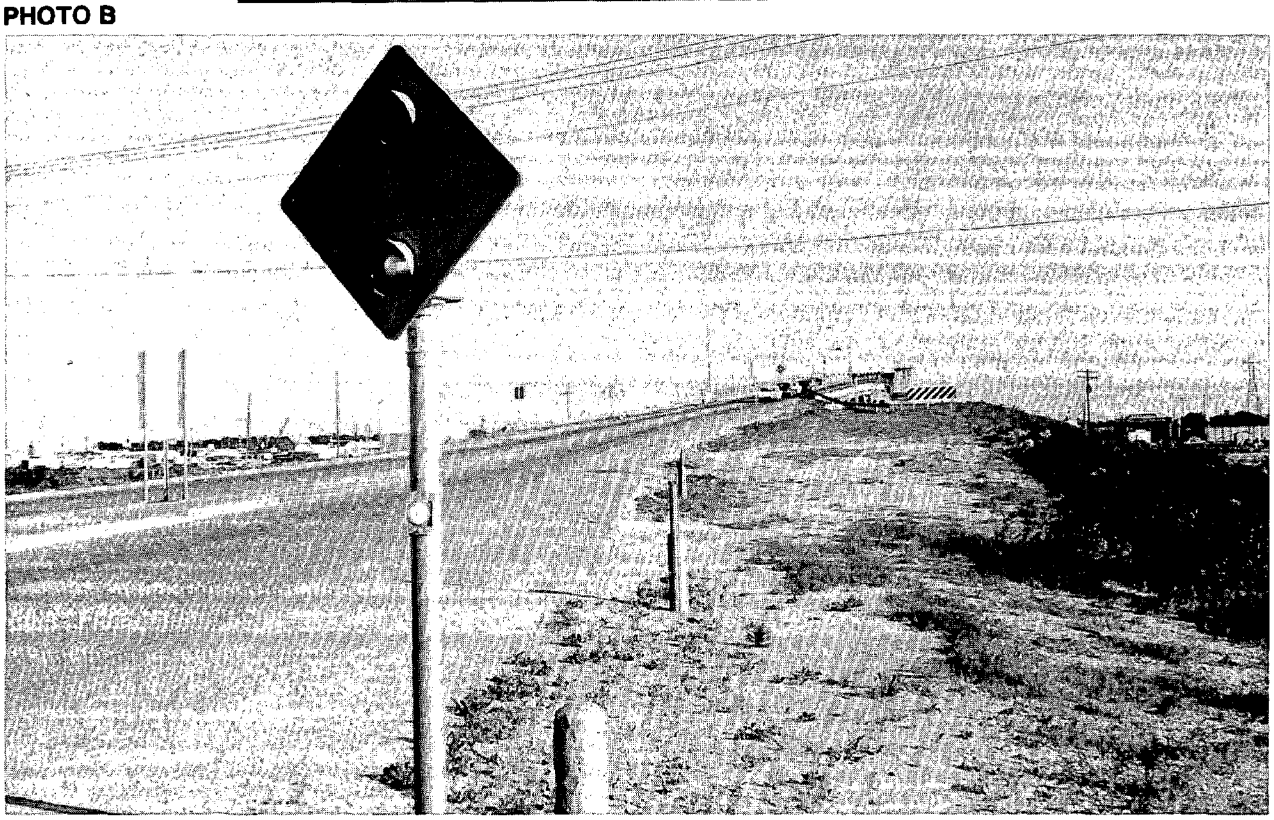


PHOTO B



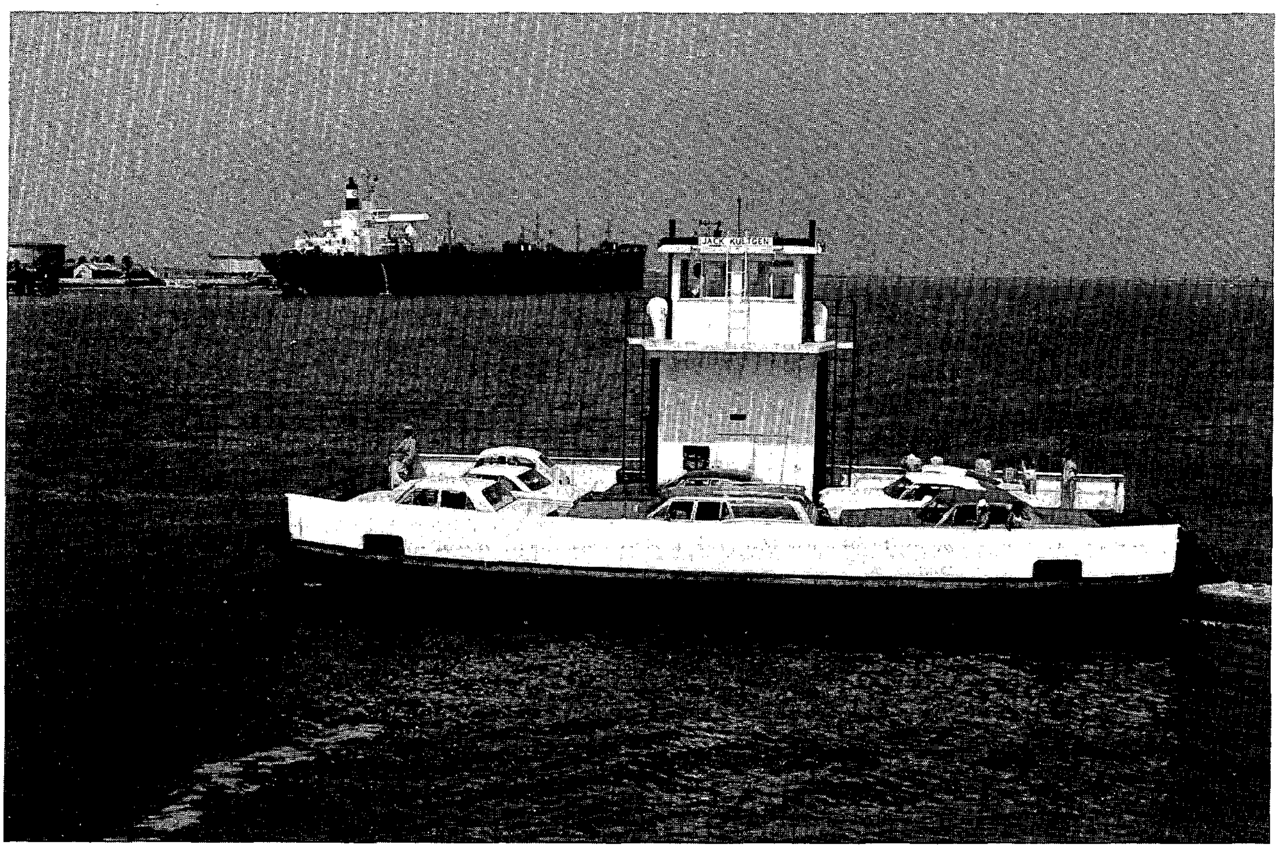
FERRIES ARE STILL OPERATING AT THREE PLACES ON THE TEXAS COAST—ONE BETWEEN GALVESTON ISLAND AND PORT BOLIVAR, ONE BETWEEN PORT ARANSAS AND ARANSAS PASS, AND ONE ACROSS THE HOUSTON SHIP CHANNEL AT LYNCHBURG NEAR THE SAN JACINTO BATTLEGROUND. ALTERNATE ROUTES OF EGRESS EXIST IN ALL CASES, BUT THE FERRIES ARE ALSO UTILIZED. HOWEVER, SINCE THE FERRIES CEASE OPERATION WHEN WINDS REACH TROPICAL STORM INTENSITY (38.5 M.P.H.) OR THE TIDES REACH FIVE FEET, THEIR EFFECTIVENESS AS A MEANS OF EVACUATION IS LIMITED.

PHOTO A—GALVESTON ISLAND-PORT BOLIVAR FERRY.

PHOTO B—PORT ARANSAS-ARANSAS PASS FERRY.

PHOTO A

PHOTO B



STORM SURGE CAUSED BY HURRICANES OFTEN CUTS COMPLETELY THROUGH BARRIER ISLANDS AND PENINSULAS. MORE THAN 130 WASHOVER CHANNELS HAVE OCCURRED ALONG TEXAS COAST BARRIER ISLANDS. SUCH WASHOVERS CAN BE WIDE AND CUT TO A DEPTH OF SEVERAL FEET BELOW SEALEVEL.

A LARGE WASHOVER CHANNEL ACTIVE DURING HURRICANE BEULAH IN 1967 IS NOW THE SITE OF MAJOR DEVELOPMENT AS EVIDENCED BY PHOTOS A, B AND C. SINCE STORMS TEND TO REACTIVATE THE SAME WASHOVER CHANNELS, THESE STRUCTURES ARE PARTICULARLY VULNERABLE TO HURRICANE DESTRUCTION. MAN'S ACTIONS, SUCH AS REMOVAL OF FILL MATERIAL FROM BEACH AREAS, CONSTRUCTION OF CHANNELS A SIGNIFICANT DISTANCE ACROSS ISLANDS, OR DUNE DESTRUCTION, CAN INCREASE THE LIKELIHOOD OF A WASHOVER OCCURRING AT A PARTICULAR SITE.

PHOTO A—STRUCTURES NOW PRESENT IN SOUTH PADRE WASHOVER CHANNEL.

PHOTO B—1974 AERIAL PHOTO OF SOUTH PADRE ISLAND WITH LOCATION OF WASHOVER CHANNELS INDICATED.

PHOTO C—1967 AERIAL PHOTO OF SOUTH PADRE ISLAND SHOWING WASHOVER CHANNELS.

PHOTO A

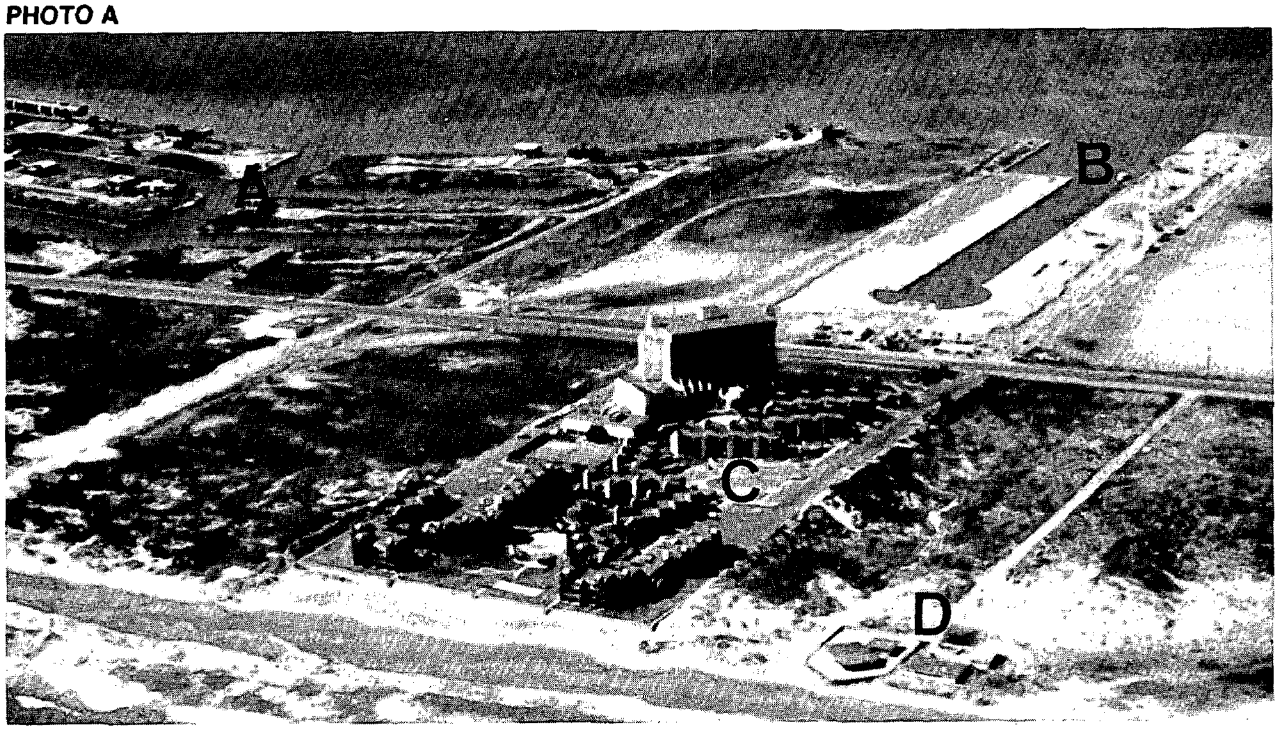


PHOTO B

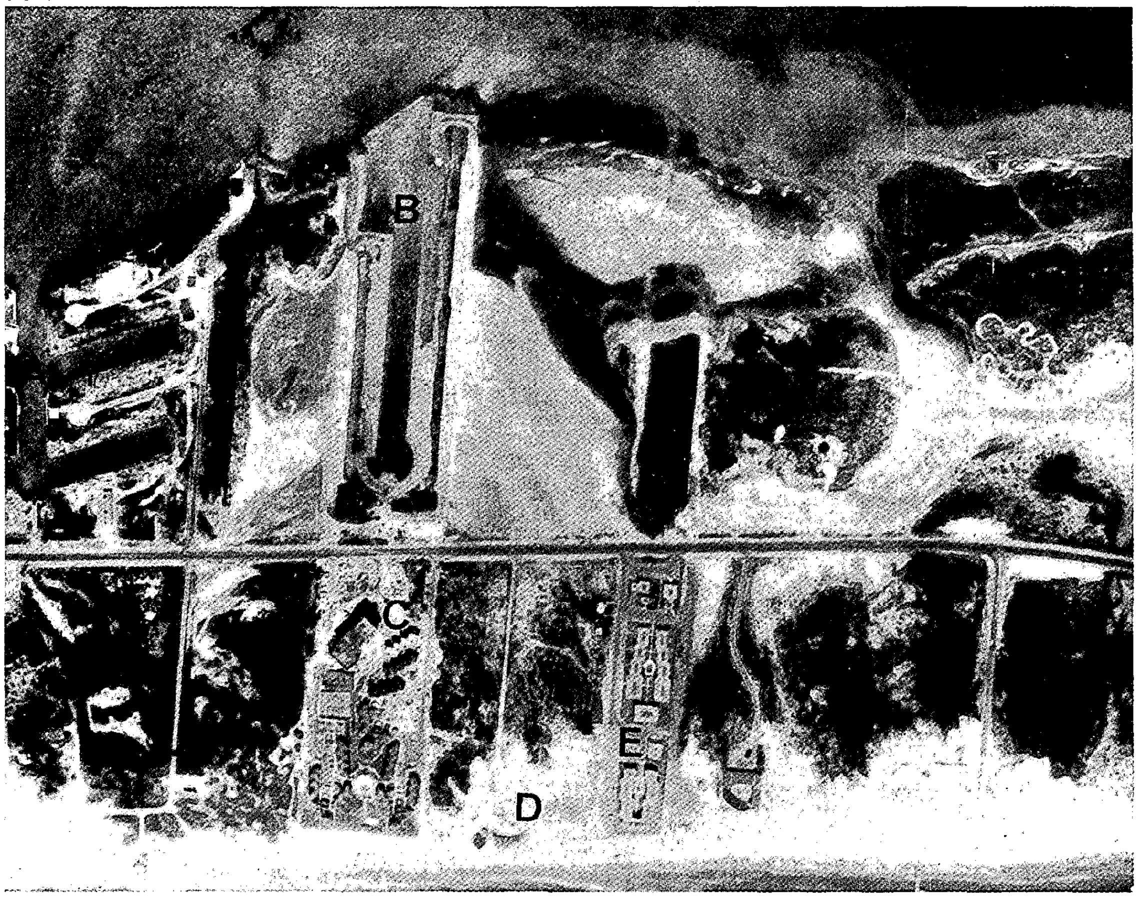
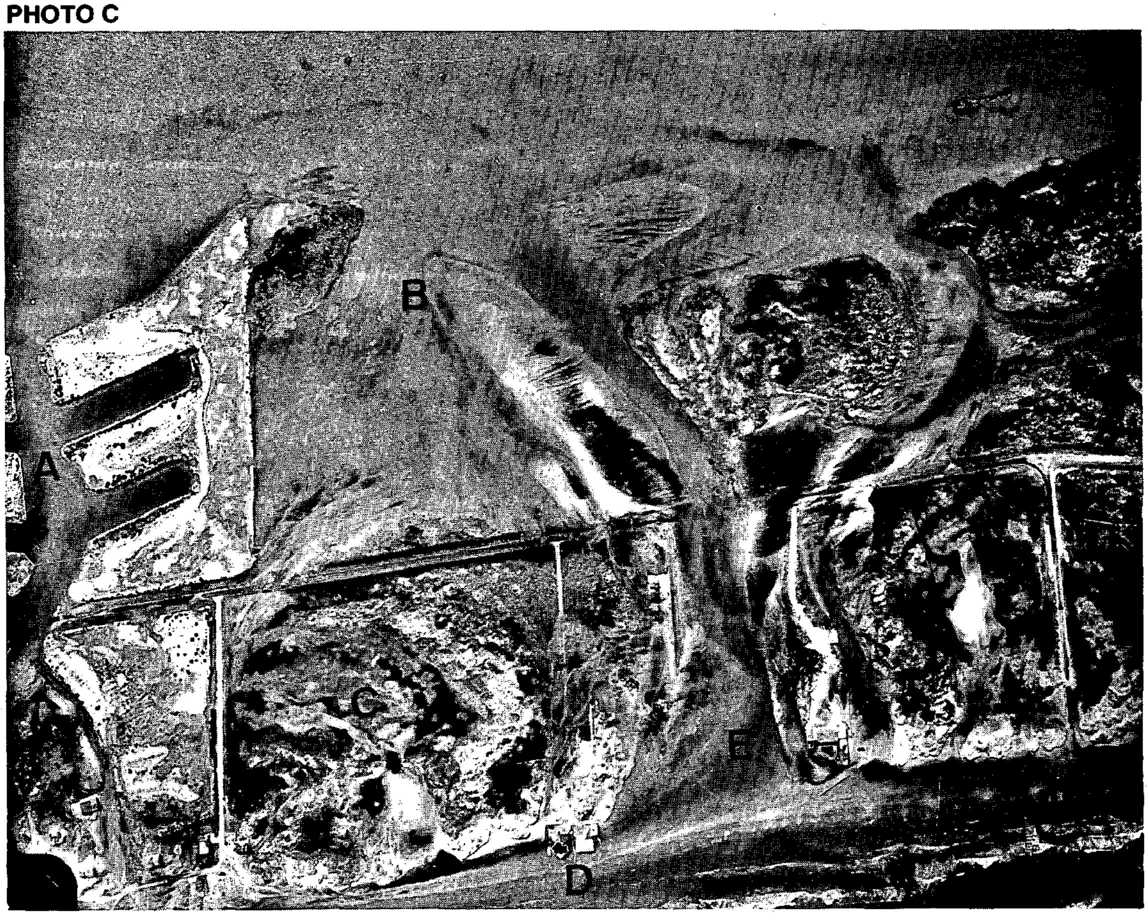


PHOTO C



CHRONIC OR CONTINUING EROSION, NOT CAUSED BY A PARTICULAR STORM OR HURRICANE, IS OCCURRING ON THE TEXAS COAST. SEVERE EROSION (MORE THAN 10 FEET PER YEAR) IS TAKING PLACE IN THE SARGENT'S BEACH AREA LOCATED DIRECTLY EAST OF MATAGORDA PENINSULA (Photo A). RECENT RATES OF EROSION OF BETWEEN 5 AND 10 FEET PER YEAR HAVE CAUSED DESTRUCTION AND ABANDONMENT OF HOMES IN THE COMMUNITY OF SURFSIDE (Photos B & C). HOWEVER, WHILE THE SURFSIDE BEACH IS NOW IN AN EROSIONAL STATE, THE BEACH HAS ACTUALLY ACCRETED SEVERAL HUNDRED YARDS OVER THE PAST CENTURY. A MAP MADE OF THE AREA IN THE 1850'S INDICATED THE BEACH LINE TO BE FAR INLAND OF ITS CURRENT LOCATION.

THE FOLLOWING LONG-TERM EROSION IS OCCURRING ALONG THE 367 MILES OF GULF SHORELINE:

- SEVERE—GREATER THAN 10 FEET/YEAR—47 MILES (13%)
- MODERATE—FROM 5 TO 10 FEET/YEAR—50 MILES (14%)
- MINOR—UP TO 5 FEET/YEAR—104 MILES (28%)

THE REMAINDER IS EITHER IN EQUILIBRIUM OR ACCRETING. OF THE APPROXIMATELY 1100 MILES OF BAY-LAGOON SHORELINE, IT IS ESTIMATED THAT 408 MILES (37%) IS ERODING.

PHOTO A—EFFECTS OF EROSION ON SARGENT BEACH (1974 photo). IN 1974 ANOTHER ROW OF HOUSES STOOD SEAWARD OF THE HOUSE IN THIS PICTURE, WHICH ITSELF RESTED IN THE SURF. TODAY EROSION HAS ALMOST REACHED THE SPOIL MOUND LOCATED JUST SEAWARD OF THE ROW OF HOUSES IN THE BACKGROUND.

PHOTO B—DESTRUCTION DUE TO CRITICAL EROSION NEAR SURFSIDE.

PHOTO C—HOUSE LOCATED ON SURFSIDE BEACH.

PHOTO A

PHOTO B

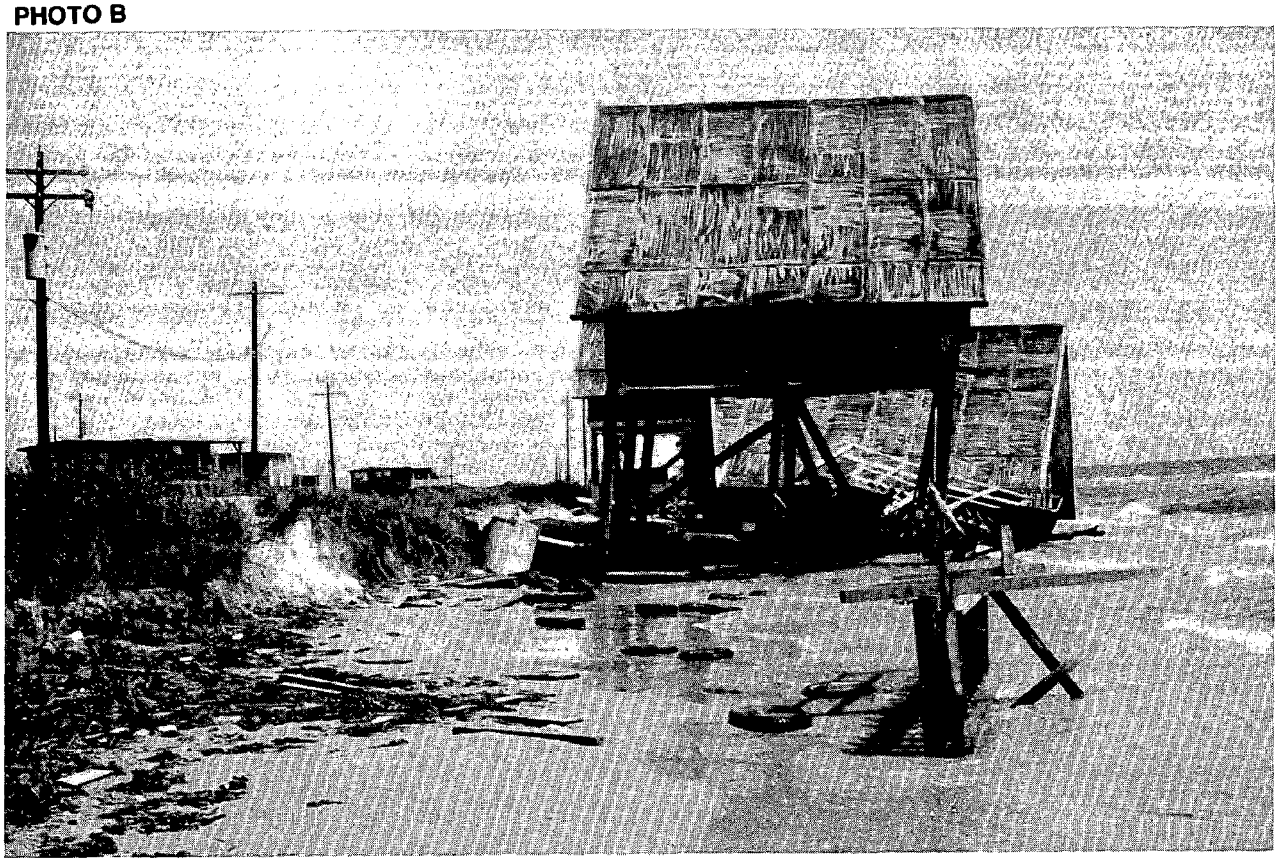
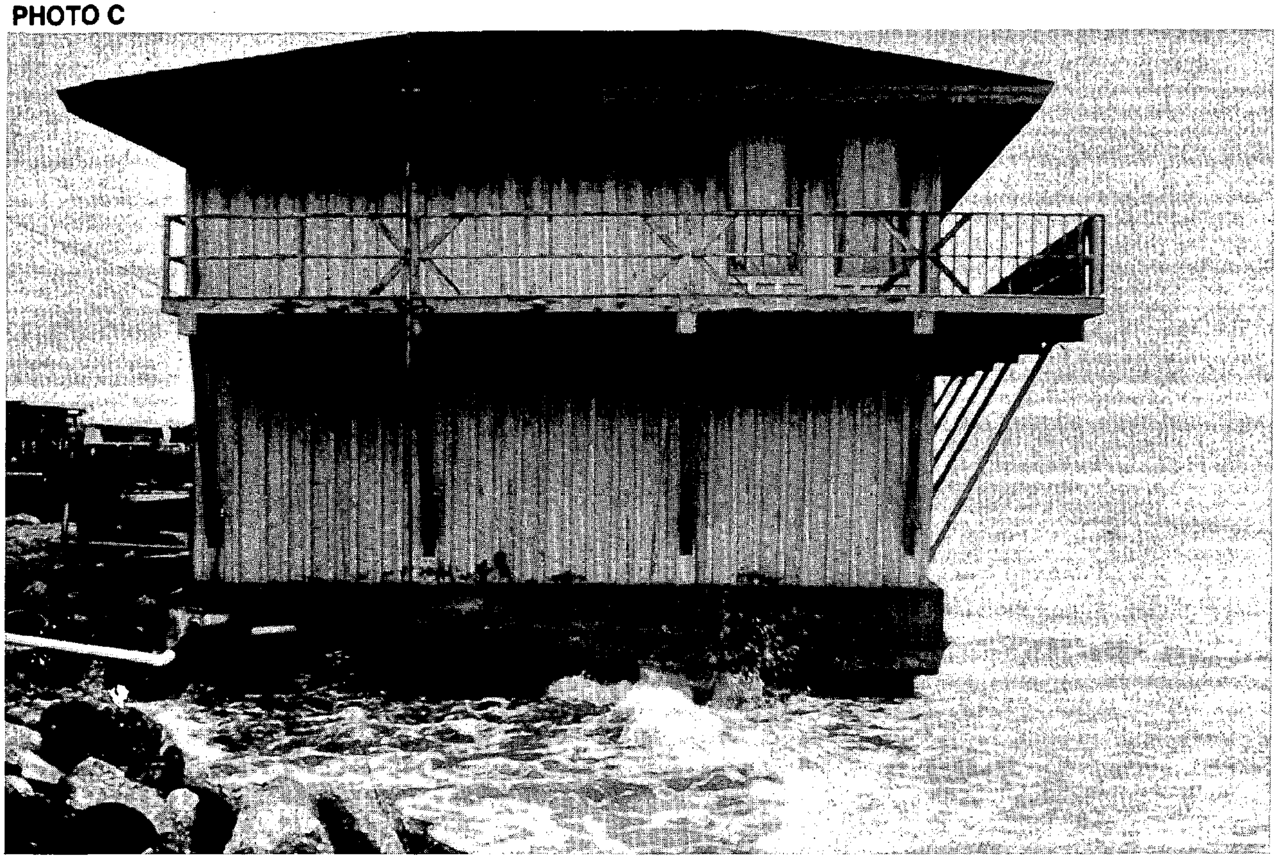


PHOTO C



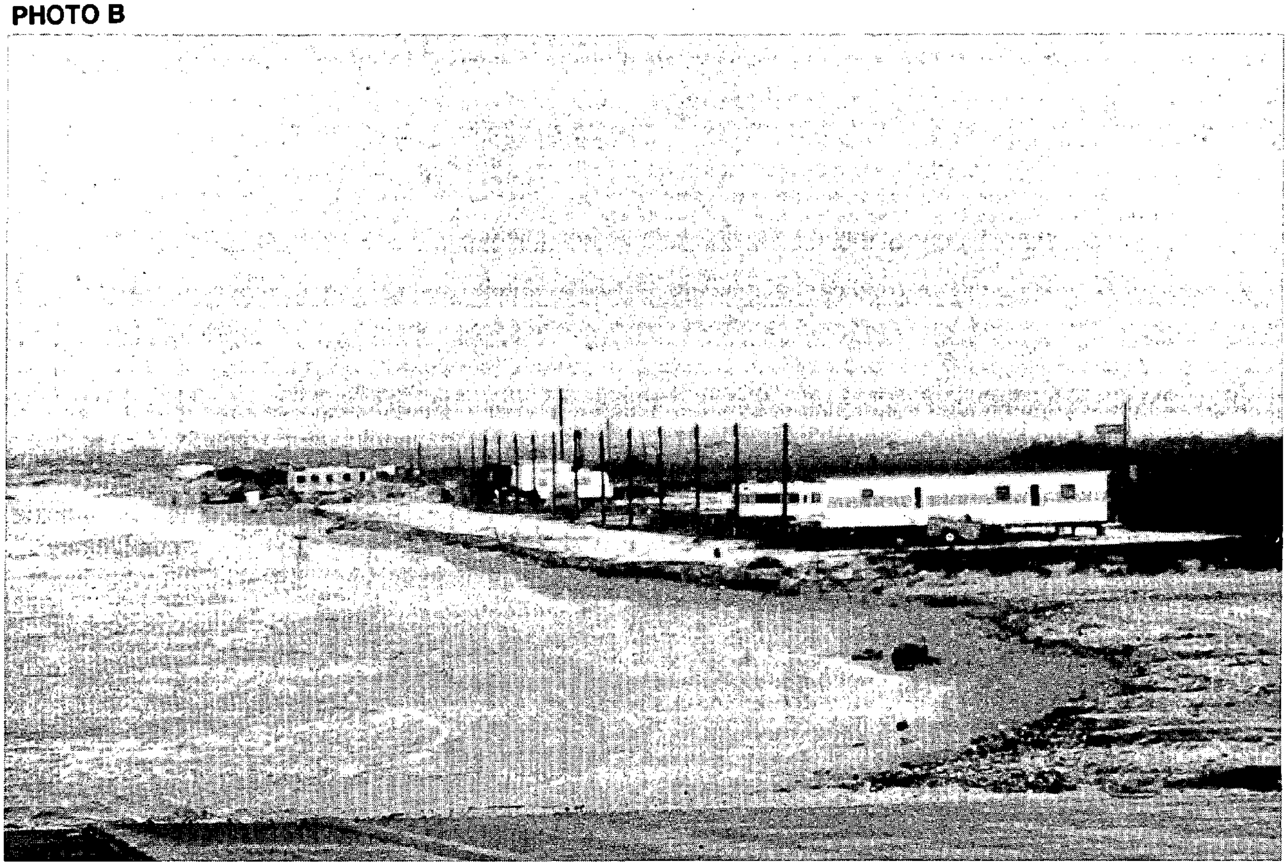
AN EXTREMELY WELL-BUILT SEAWALL WHICH CAN SURVIVE HURRICANES MAY STILL CAUSE THE LOSS OF BEACH AMENITY DUE TO EROSION (Photo A). EROSION WILL ALSO TAKE PLACE AT EACH END OF A SEAWALL (Photo B). IN ADDITION, INTERRUPTION OF THE NATURAL BEACH PROCESSES BY THE SEAWALL CAN ALSO COMPLICATE SOMEONE ELSE'S PROBLEM DOWN THE BEACH.

PHOTO A—VIEW OF GALVESTON SEAWALL SHOWING NO BEACH EXISTING IN FRONT OF SEAWALL.

PHOTO B—AREA ADJACENT TO SOUTHWEST END OF GALVESTON SEAWALL WHICH HAS ERODED MORE THAN 200 FEET SINCE COMPLETION OF THE SEAWALL EXTENSION IN 1961.

PHOTO A

PHOTO B



NATURAL PROTECTION AGAINST HURRICANE WIND AND WAVES IS PROVIDED BY VEGETATED SAND DUNES LOCATED ON THE TEXAS COAST. HOWEVER, SOME OF MAN'S ACTIVITIES ARE DESTROYING SOME OF THIS NATURAL PROTECTION. RECREATIONAL VEHICLES SUCH AS DUNE BUGGIES OR TRAIL BIKES CAN CAUSE IRREVERSIBLE DAMAGE TO THE DUNES, DESTROYING THE STABILIZING VEGETATIVE COVER ON DUNES, THUS MAKING THEM MUCH MORE SUSCEPTIBLE TO EROSIVE DAMAGE BY WIND OR WAVE ACTION.

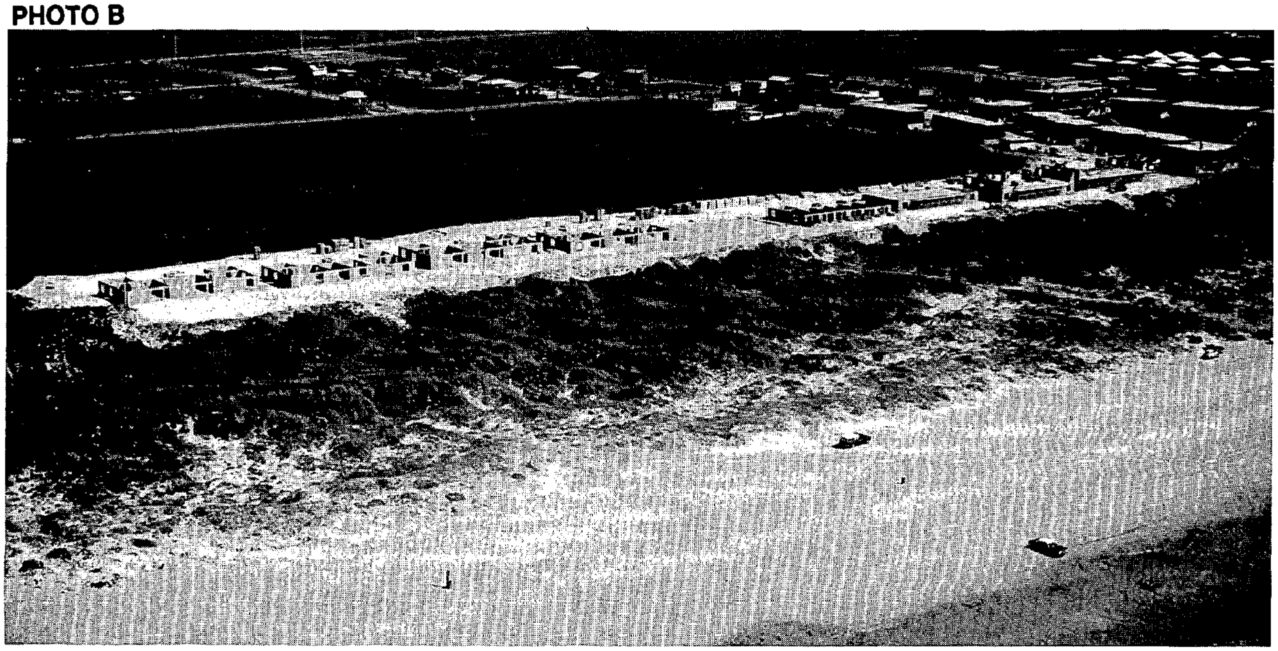
DUNES ARE OFTEN LEVELED IN ORDER TO FACILITATE BEACHFRONT CONSTRUCTION. IT SHOULD BE NOTED THAT THE CONSTRUCTION AS SHOWN IN PHOTO B HAS ALLOWED THE FOREDUNE TO REMAIN IN PLACE AND THUS RECEIVES SOME NATURAL PROTECTION.

PHOTO A—PHOTO OF DUNE BUGGY.

PHOTO B—CONSTRUCTION ON DUNE—PORT ARANSAS.

PHOTO A

PHOTO B



MOBILE HOMES ARE ONE OF THE MOST POPULAR RESIDENTIAL DWELLINGS ON THE TEXAS COAST. IF NOT ANCHORED PROPERLY, THEY CAN INFLICT SEVERE DAMAGE TO NEIGHBORING STRUCTURES WHEN LIFTED AND DRIVEN BY HIGH WINDS. UNANCHORED MOBILE HOMES WILL MOVE AT LESS THAN HURRICANE FORCE (74 M.P.H.) WINDS. STATE LAW NOW REQUIRES THAT THEY BE TIED DOWN, BUT, EVEN WITH BEST ANCHORING, MOBILE HOMES CANNOT BE EXPECTED TO SURVIVE IN A MAJOR HURRICANE BECAUSE OF STRUCTURAL WEAKNESS.

PHOTO A—MOBILE HOME PARK ON GALVESTON ISLAND.

PHOTO B—REMAINS OF LARGE TRAILER PARK IN PORT ARANSAS FOLLOWING HURRICANE CELIA IN 1970.

PHOTO A

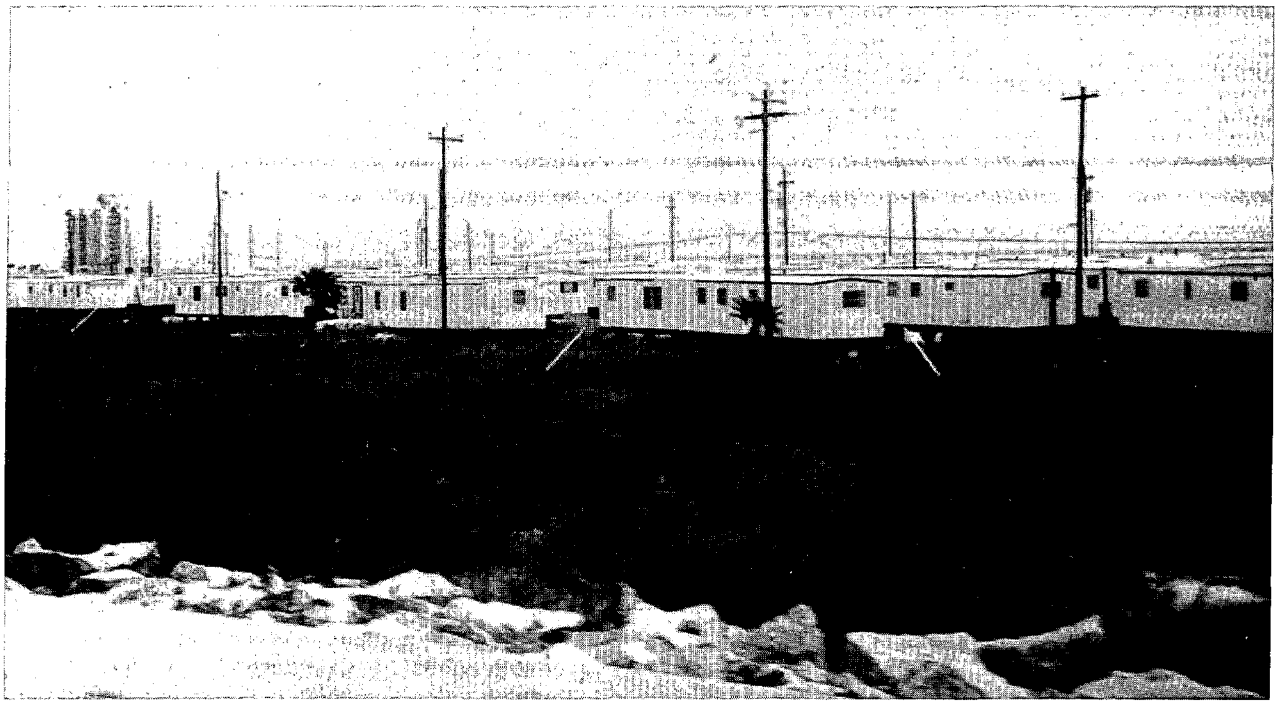


PHOTO B

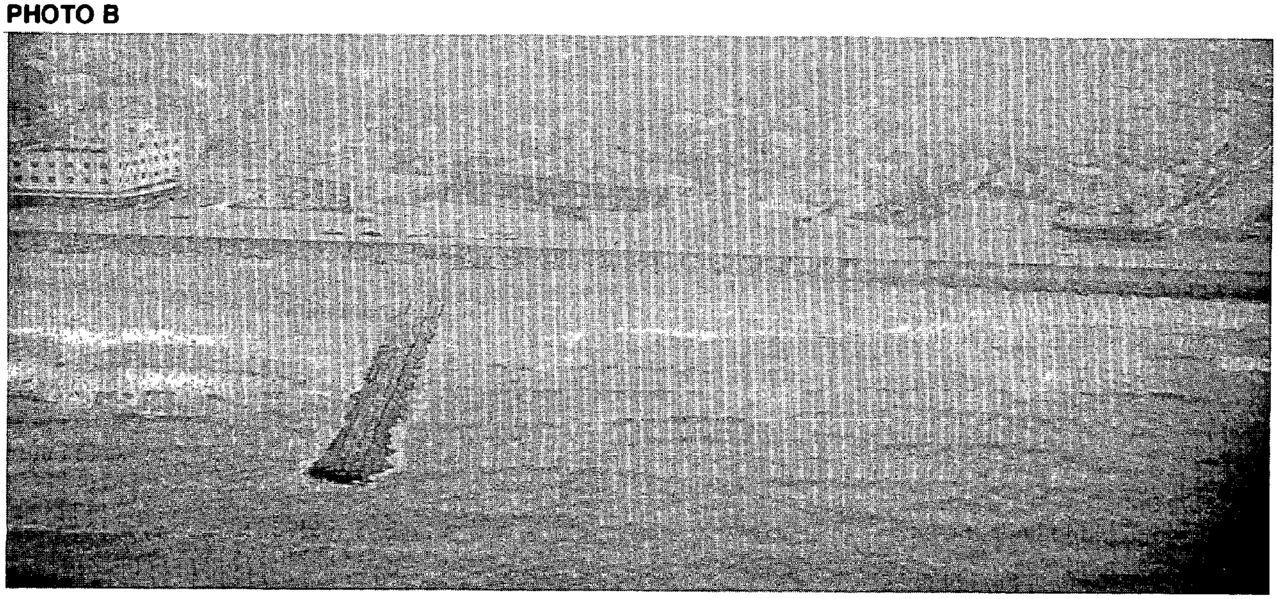
JETTIES ARE BUILT TO STABILIZE PASSES THROUGH THE BARRIER ISLANDS AND THUS MAKE COMMERCIAL NAVIGATION POSSIBLE. GROINS ARE SOMETIMES BUILT TO "TRAP" SAND AND THUS INHIBIT BEACH EROSION. SUCH STRUCTURES MAY HAVE SEVERE EFFECTS ON ADJACENT BEACHES THROUGH THE ALTERATION OF NATURAL SHORELINE PROCESSES. FREQUENTLY EROSION WILL OCCUR ON ONE SIDE WITH ACCRETION ON THE OTHER SIDE.

PHOTO A—JETTIES AT MANSFIELD CHANNEL.

PHOTO B—GROIN PROJECTING FROM GALVESTON SEAWALL.

PHOTO A

PHOTO B



REMOVAL OF SAND MATERIAL FOR CONSTRUCTION FILL HAS OCCURRED ON SOME BARRIER ISLANDS. OFTEN WHEN THIS DREDGING IS DONE, BORROW PITS OR ARTIFICIAL PONDS ARE CREATED. THESE PITS PROVIDE A READY-MADE PATH FOR HURRICANES TO CUT THROUGH THE ISLAND. SUCH BORROW PITS HAVE BEEN CREATED AT THE END OF THE GALVESTON SEAWALL AS MATERIAL HAS BEEN DREDGED TO RAISE LAND IN AREAS BEHIND THE SEAWALL. SUCH PRACTICES HAVE LARGELY BEEN STOPPED BY STATE LAW.

PHOTO A—AERIAL VIEW OF THE GALVESTON SEAWALL WITH BORROW PITS LOCATED AT THE WALL'S SOUTHWEST END.

PHOTO B—CLOSEUP VIEW OF GALVESTON ISLAND BORROW PITS.

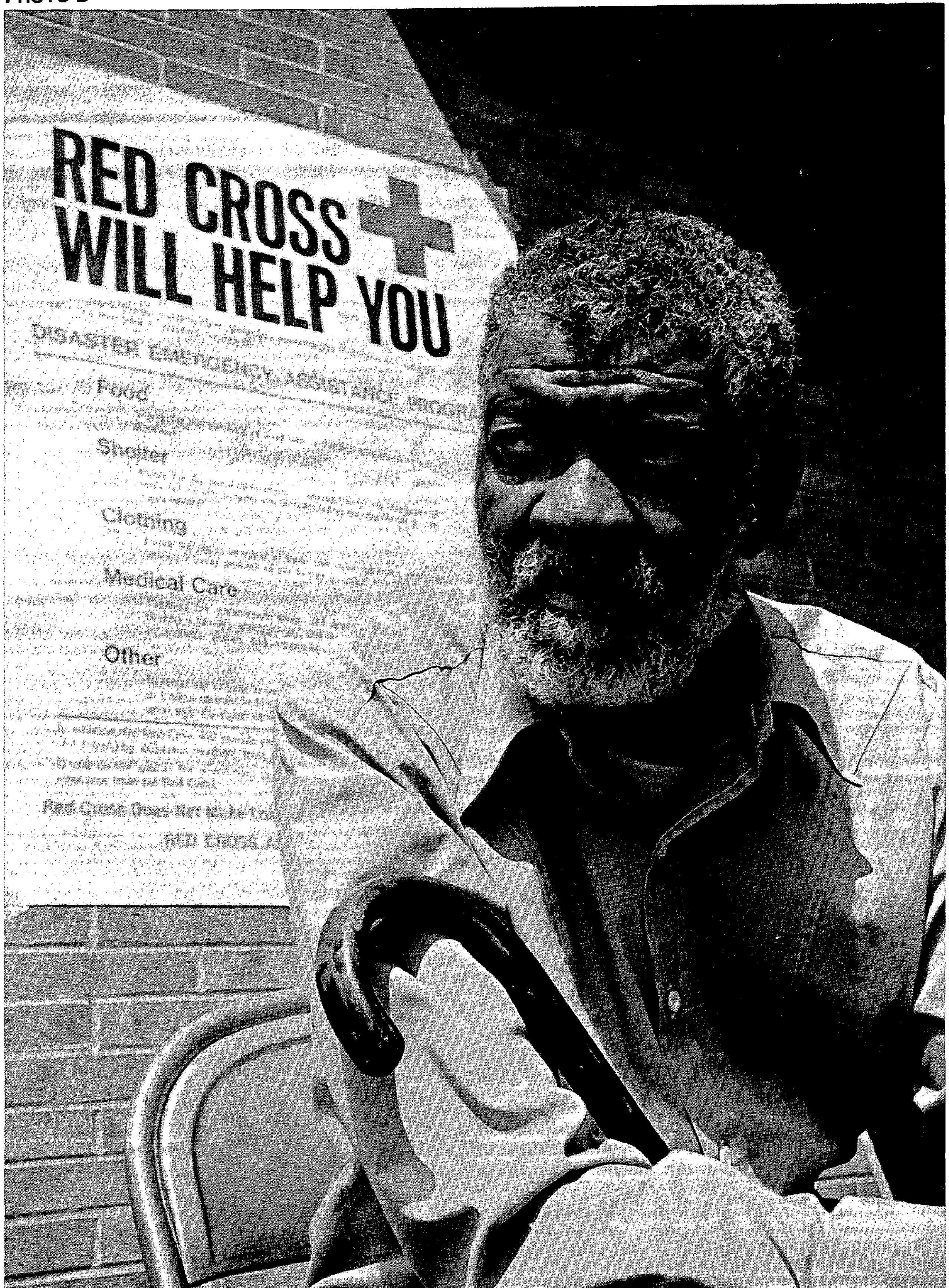
PHOTO A

PHOTO B

HUMAN SUFFERING IS ONE ASPECT OF NATURAL HAZARD DISASTER SITUATIONS OFTEN OVERLOOKED. DESTRUCTION OF BUILDINGS, FLOODING OF STREETS, ETC., ARE GRAPHICALLY PORTRAYED, BUT HUMAN SUFFERING AND LOSS ARE NOT USUALLY GIVEN AS MUCH ATTENTION. ON THE TEXAS COAST, THE POTENTIAL FOR HUMAN SUFFERING IS GROWING EQUALLY AS QUICKLY AS THE POTENTIAL FOR LOSS OF PROPERTY.

PHOTO A

PHOTO B


RED CROSS
WILL HELP YOU
DISASTER EMERGENCY ASSISTANCE PROGR
Food
Shelter
Clothing
Medical Care
Other

APPENDIX A

HURRICANES

Hurricanes are the most destructive storms which affect wide areas of the Texas coast. On the average, since 1900, hurricanes have hit some part of Texas once every two to three years and have claimed over 7,000 lives and caused over 1.3 billion dollars in property damage. Hurricanes push large volumes of sea water ahead of the storm which inundate low-lying coastal areas. This process is called storm-surge flooding and is the most destructive storm effect along the Texas coast. Fresh-water flooding due to torrential hurricane rainfall can also be extremely destructive near overflowing creeks and rivers, and in naturally low-lying areas. Rainfall rates become much heavier as a hurricane makes landfall and its forward movement is reduced. When hurricane Audrey struck near the Texas-Louisiana border in 1957, some 40,000 to 50,000 cattle were killed, mostly by drowning. Indeed, nine out of ten human victims of hurricanes result from drowning, when low-lying barrier islands and mainland areas are flooded.

Hurricanes are defined as storms having winds over 74 mph, but winds of 100 to 135 mph are common and may occur over a 300 mile wide area. Severe storms have wind velocities of 135 to 160 mph. Damage to structures results from sudden pressure changes associated with gusts; mobile homes are particularly vulnerable to wind damage. Hurricane Carla, which struck near Port O'Connor in 1961, had sustained winds of about 175 mph, and Camille, which struck the Mississippi coast in 1969, packed winds of 200 mph.

During the past 70 years, most coastal areas in Texas have experienced severe weather from impact or fringe effects of a hurricane. Three hurricanes which have made landfall in the Texas coastal zone since 1960 have had distinctively different major effects, and have varied greatly in the size of the area impacted (Fig. 1 and Table 1).

Hurricane Carla (1961) was a very intense hurricane with a storm surge in excess of 10 feet above mean sea level (MSL) at Port O'Connor and of 22 feet above MSL at Port Lavaca; she was probably one of the largest hurricanes for which there are reliable records. Parts of Matagorda Peninsula were breached by storm channels and shorelines were eroded as much as 800 feet under the action of huge storm waves (McGowen and Brewton, 1975). During Carla, Corpus Christi, which was 50 to 60 miles from the storm center, experienced peak gusts of 85 mph; total damage from this storm exceeded 400 million dollars.

Hurricane Beulah (1967) carried lower maximum winds (Fig. 1) and resulted in a storm surge of 10 feet above MSL at Brazos Santiago. During movement over land, Beulah produced torrential rainfall in excess of 30 inches during the four or five days of aftermath storms. At least 115 tornadoes accompanied the hurricane, with some as far inland as Austin.

Hurricane Celia (1970) carried minimal rainfall, and a storm surge of less than 9 feet above MSL was restricted to a very narrow zone. The hurricane wind pattern had a diameter of 80 miles, making Celia a very small storm. At the time the storm made landfall, however, the eye decreased in size by about 40 percent and wind velocity increased from 90 to 130 mph with gusts of 160 to 180 mph. These winds were highly damaging, leaving distinct paths of destruction through the Corpus Christi area.

This brief synopsis of hurricane effects should give the potential coastal property owner an appreciation of the awesome power of these intense storms. The National Weather Service recently pointed out that if Carla returned today at least 50,000 more

Variables	*Beulah* type	*Carla* type	*Celia* type
Wind	Moderate	Moderate	High
Storm-surge tides	Moderate	High	Low
Rainfall	High	Moderate	Low
Size of destructive core	Medium	Large	Small
Length of aftermath effects	Extended	Intermediate	Brief
Character of coastline affected	Port Mansfield: poorly vegetated, low relief, broad unrestricted bay	Port O'Connor: well vegetated, local relief to 30 feet, funnel-like Lavaca Bay	Port Aransas: moderate vegetation, local relief to 30 feet, funnel-like Nueces Bay

Table 1. The characteristics of basic types of hurricanes striking the Texas Coastal Zone. From Brown and others (1974).

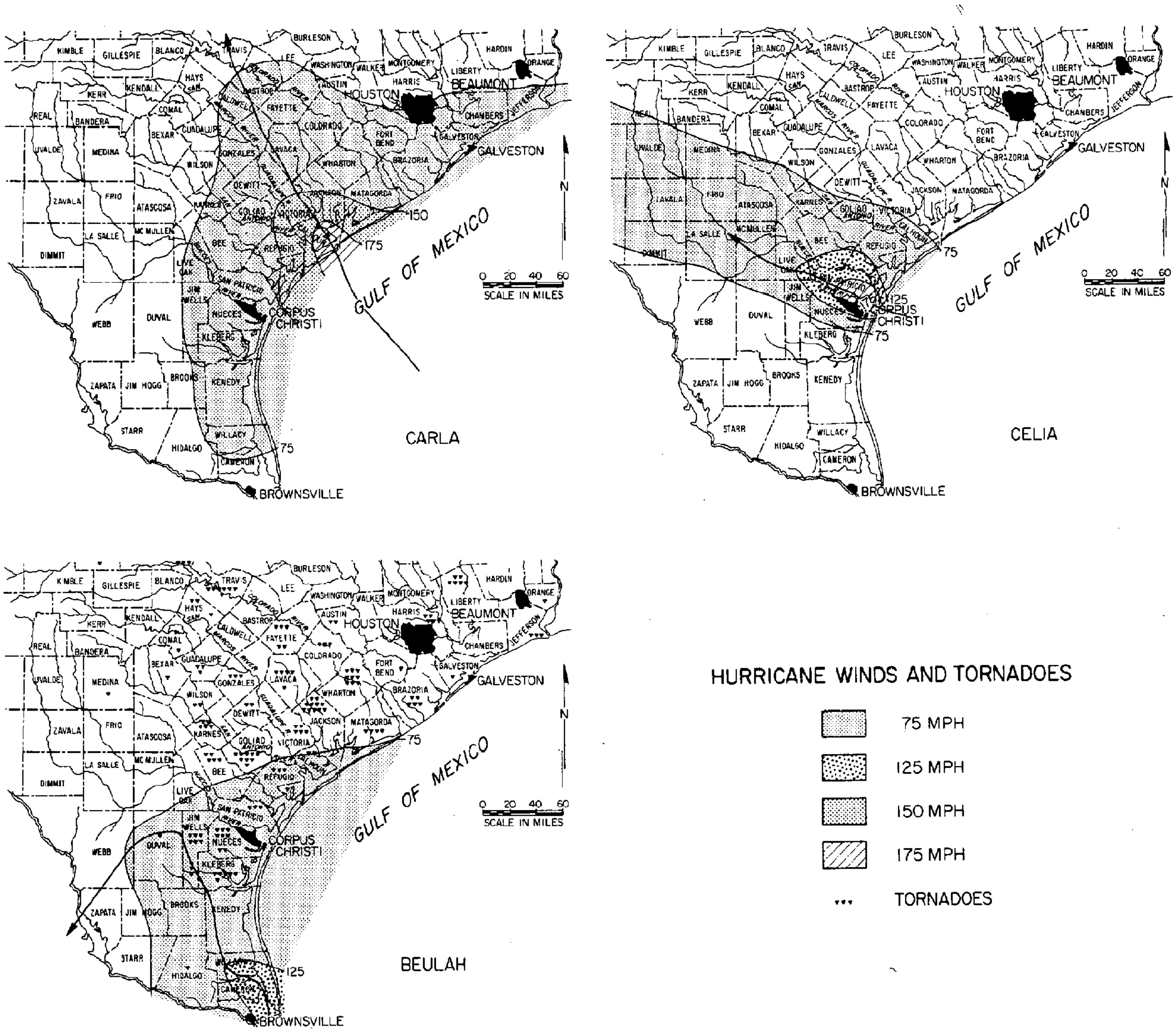


Figure 1. The track of the eyes of Hurricanes Carla, Beulah and Celia, and the area covered by hurricane-level winds, Texas Coastal Zone. From Brown and others (1974).

people would be directly affected. A critical problem in the effort to avoid loss of life and to minimize storm damage to property is the lack of hurricane experience of many new coastal residents. The need for awareness of the hurricane danger and the need for preparedness planning increase as the population increases in vulnerable coastal areas.

HURRICANE RELATED EFFECTS

Washover Channels

One of the principal effects of hurricane storm surge is the development of washover channels that breach barrier islands or peninsulas. These channels readily develop at sites of wind erosion (blowouts) or in areas of poorly developed fore-island dunes and beach ridges. Storm-surge waters flow landward through the channels, scouring sand. Following passage of the hurricane, elevated bay and lagoon waters also return to the Gulf through these channels. Storms tend to reactivate the same washover channels, which are closed at their gulfward end by shoreline processes during non-storm conditions. Construction within or immediately adjacent to hurricane breach or surge channels may lead to property damage in the event of hurricane landfall.

Waves

Storm waves, superimposed on the hurricane storm surge, cause severe erosion of shorelines and extensive damage to structures. Breaking waves can destroy many buildings, but their destructive potential is greatly increased by pilings, uprooted trees and other debris that act as battering rams. Although accretion between storms may restore much of the shoreline lost during a hurricane, the shoreline may retreat several hundred feet in a few hours during hurricane wave attack.

Wind

Hurricane winds deserve special mention because they can be particularly damaging, even in the case of small storms such as hurricane Celia. Due to the increased risk of wind damage, coastal counties are in the Windstorm Catastrophe Insurance Pool. Property seaward of the Gulf Intracoastal Waterway is usually subject to greater insurance premiums for wind damage coverage, since this area must face the full impact of hurricane winds as the storm comes ashore. This zone is often referred to as the "beach zone" with respect to wind damage potential.

WIND TIDAL FLOODING

Most severe weather in the coastal region, other than hurricanes, tropical storms and thunderstorms, is related to frontal systems, or "northers". In the winter, polar fronts may move rapidly into the coastal area, bringing low temperatures, rain, and strong northerly winds. Locally heavy rainfall may occur. The northerly winds may generate high water levels that inundate tidal flats and other low areas, especially on the southern margin of bays and the back sides of barrier islands. Wind-tidal flooding is slow and does not present a serious hazard, but it may be a hazard for property at low elevations along bay and lagoon margins.

F. I. A. FLOOD HAZARD

The Federal Insurance Administration has designated flood hazard zones which determine eligibility and applicable rates for property flood insurance. These zones include: A, an area of special flood hazard (having a 1-percent chance of being flooded each year), with subcategories A1 through A30 assigned according to flood hazard factors; AO, an area of special flood hazard with flood depths less than 2 feet and/or unpredictable flow paths; V, an area of special flood hazard with velocity that is inundated by tidal floods; B, an area of moderate flood hazard; C, an area of minimal flood hazard, and D, an area of undetermined, but possible, flood hazard. The Federal Insurance Administration provides large-scale maps showing flood hazard area boundary and rate information for incorporated and unincorporated areas. A local insurance agent or broker should be consulted to determine how these designations affect a particular piece of real property.

SHORELINE EROSION AND ACCRETION

Gulf Shorelines

Shorelines are naturally or through man's influence in a state of erosion, accretion or equilibrium. Erosion, which produces a net loss of land, is the most critical situation, while natural accretion of shorelines, which produces a net gain in land is generally a desired condition. Accretion may pose a problem in some situations, however, where accreting materials may block navigation channels or limit access to docks and canals.

Shorelines change in response to tides, storms, sediment supply and relative sea level changes. Historical studies indicate that long-term erosion during the past 74 to 132 years has subjected 46 linear miles (13 percent) of the Texas Gulf shoreline to severe erosion (over 10 feet per year), and 154 miles (42 percent) to moderate erosion (up to 10 feet per year). Short-term erosion during the past 7 to 23 years has subjected 153 linear miles (42 percent) of the Texas shoreline to severe erosion and 101 miles (28 percent) to moderate erosion (Brown and others, 1974; Morton, 1974, 1975). Thus, recent data indicate that over two-thirds of the Texas Gulf shoreline is undergoing erosion.

Most beaches undergo short cycles of erosion and accretion no matter what the long-term trend. These cycles are in response to day-to-day conditions such as storm-wave frequency, seasonal wind patterns, and, locally, the opening and closing of periodically active tidal inlets. Superimposed on these natural processes are man's activities, such as the building of seawalls, jetties, and groins, and the alteraion tion of both dune lines and vegetation. Although shoreline control and stabilization structures may alleviate an erosion problem in one area, they frequently increase problems in a nearby area which loses its supply of sand due to the impoundment, or the sand-trapping effect of the structure. By interrupting the lateral drift of sand, along the shoreline, structures such as seaward-projecting stone jetties and groins can result in sand-starved conditions and consequently, long-term erosion of beaches downdrift from the coastal structures.

A logical conclusion which can be drawn from available information is that shoreline position will continue to change, and erosion, or landward retreat, will be the ultimate long-term trend. The combined effects of diminishing sand supply and the impact of tropical cyclones is insurmountable except in very local areas such as river mouths. No evidence exists that a long-term reversal of shoreline erosion will occur to change the present trend. When coastal development plans are being formulated, careful consideration should be given to evidence that shoreline erosion will continue. This map should aid potential property owners to evaluate trends of erosion and accretion in their area. While Gulf beach-front property may demand the highest prices, it may also carry with it the greatest risks from storms and long-term erosion.

Bay Shorelines

While research on precise rates of bay-shore erosion has not been completed, except for Matagorda Bay and parts of Corpus Christi Bay, areas of bay shoreline undergoing erosion have been mapped. Approximately 37 percent of the Texas bay-estuarine shoreline is currently undergoing erosion. The distribution of these eroding segments is principally related to the dominant winds as well as to hurricanes and tropical storms. Wind strength and duration, depth of water, and orientation of bay shorelines are factors controlling bay shoreline erosion. As on Gulf beaches, erosion leads to a loss in land area, and can be a serious hazard to bay-margin structures.

LAND SUBSIDENCE

Land subsidence, both amount of land elevation lost and area affected, has been increasing significantly in Harris and Galveston counties during the past three decades. Subsidence is related primarily to production of some 500 million gallons of ground water per day. Ground water withdrawal results in the nearly irreversible compaction of clays associated with the water-producing sands, and even if all ground water pumping would stop today, some subsidence would probably continue for many years. Much smaller areas of subsidence in other coastal counties may be related to local oil production.

The greatest hazard from subsidence in areas surrounding Galveston Bay is an increase in susceptibility to flooding by hurricane storm surge waters. From 1943 to 1973, total property damage and loss from marine inundation caused by subsidence in the Houston-Baytown area is estimated to be 113 million dollars. A 6-foot tide associated with tropical storm Delia in 1973 resulted in subsidence-related damages estimated at over 53 million dollars (Kreitler, 1976a). Some areas, such as a part of the Brownwood subdivision, Baytown, Texas, have completely subsided beneath sea level.

In 1961, Hurricane Carla with a peak flood surge of 16.4 feet, flooded 123 square miles of Harris and Galveston Counties surrounding Galveston Bay. Subsidence which has occurred between 1961 and 1976, will expose at least an additional 25 square miles (a 20 percent increase) to tidal flood waters resulting from a hurricane of the same magnitude and characteristics as Carla. The environmental impact of subsidence in this area is great because of the high population density, low elevation, and proximity to the Gulf of Mexico.

SURFACE FAULTING

A fault is a fracture in the earth along which movement has occurred. A surface fault is the surface expression of a fault which may extend to depths of several thousand feet. A surface fault forms a linear rupture of the land surface that can be identified by breaks in man-made structures and/or the presence of a linear topographic escarpment. Surface faults are important to property owners because gradual movement along the fault surfaces can damage homes and other structures, crack or buckle streets, highways and runways, and damage utility structures, such as pipelines.

Evidence (Kreitler, 1976a; 1976b) suggests that the same ground water withdrawals, which contribute to land surface subsidence have contributed to activation of surface faults. Differential land subsidence (uneven loss of land elevation over a short distance) occurs where faults are activated. This process of fault movement, coupled with land surface subsidence, can adversely affect the quality of the present or future land use in a particular area. In Harris and Galveston Counties, for example, several surface faults have been activated. These faults intersect two airports, interstate highways at 11 different locations, railroad tracks at 28 locations, and pass through 11 communities in which more than 200 houses evidence fault damage.

Faults in the Texas Coastal Zone need not be a problem. Future construction on faults can be avoided, and where this is impossible the awareness of faults will permit architects and engineers to design structures which can withstand the low rates of differential movement. Faults along the Texas Coast are not associated with earthquake activity.

APPENDIX B

Coast Disaster Potential High

GALVESTON, Tex. (AP) — A meteorologist said Wednesday land subsidence in the Galveston Bay area has created a major disaster potential for the approaching hurricane season.

Davis Benton, meteorologist in charge of the National Weather Service in Galveston, said more than 100,000 persons could be trapped by high tides.

The *Gulf of Mexico* hurricane season opens Tuesday.

Benton said the subsidence situation dictates a need for early evacuation

Gulf Residents Warned To Have Evacuation Plans

BY RICHARD FLY
Chronicle Staff

With the Gulf Coast in the six-month hurricane season the National Weather Service in Galveston is advising area residents to make plans for safety or evacuation in the event of a storm.

The season lasts from June 1 through Nov. 30, but the majority of storms which have come ashore between Galveston Bay and Freeport in the past century have occurred in August and September.

Of the 42 hurricanes and tropical storms experienced in the last 100 years, 26 have occurred in those two months.

The last time a full hurricane hit this area was 1961, when Carla swept inland, leaving 46 dead and more than $400 million in property damage in its wake.

'Planned disaster' is topic of Tropical storm seminar

If a hurricane the magnitude of Carla were to strike Galveston this year, the storm would affect the lives and property of 50,000 people, inundate portions of Interstate 35, and trap the residents of Galveston on the island.

This is the prediction of Dr. Christopher C. Mathewson, Department of Geology, Texas A&M University, and a subject he will pursue further at the Friday's Tropical Storm Seminar sponsored by A&M in Galveston.

According to Mathewson, man is contributiong to the damage potential of hurricanes by his development of coastal regions, because urbanization increases run off problems which, with subsidence in the Houston areas, contributes to the danger of flooding.

More importantly, Mathewson is concerned with coastal development which he terms " a planned disaster."

"The planned disaster is the beautifully planned community common along the Texas coast," he explained. "The people buying residences in these communities seem to think that the expensive price tag implies that their home is hurricane-proof. Add to this a false sense of security created by the sea wall, and the general disregard for hurricanes as a natural process and it all spells trouble."

Hurricanes

Official admits Houston overdue

There're many things to do, even when caught unaware

By JIM MALONEY
Post Reporter

Dr. John C. Freeman Jr. is not predicting a hurricane for the Houston-Galveston area during the official six-month season which began Tuesday, but says, "I will agree we are overdue."

The director of the Institute for Storm Research at the University of St. Thomas noted that it has been since September 1961 that this area has felt the effect of a hurricane.

THAT IS WHEN Carla — the largest storm of record to ravage the Texas Coast — made landfall at Port O'Connor, some 125 miles south.

That may seem pretty far away for Carla to be felt here, but her strength was such that her damage was felt not only along the entire Texas Coast, but inland as far away as the Dakotas.

Since Carla's visit, smaller hurricanes [illegible]e delivered their fury along other [illegible]s of the Gulf Coast.

IF NEWCOMERS SINCE Carla do not think the Houston-Galveston area has been fortunate, they should be aware that five hurricanes and three tropical storms have since struck other regions of the state's coast.

Study says erosion hits most of coast

AUSTIN (AP) — As much as 70 per cent of the 367-mile Texas Gulf shoreline has lost some land to erosion in recent years, says a report by the Bureau of Economic Geology.

The bureau, part of the University of Texas at Austin,

5-foot tides would 'virtually isolate' Galveston

(EDITOR'S NOTE: A team of meteorologists at Texas A&M University's Center for Applied Geoscience with the help of the Sea Grant Office has prepared three booklets to help Texans understand, prepare for, and recover from the harmful effects of hurricanes. In this last in a three-part series, the actions that may be taken to minimize hazards and save lives are discussed).

Here Are Main Routes That Might Become Impassable

The following are some of the main routes leading out of coastal areas with less than eight foot elevations above mean sea level (MSL). The figures indicate their elevation. If tides reach that level the roads probably will become impassable.

Galveston Island

Five-foot tides would virtually isolate Galveston Island from the mainland.

Five-foot tides will isolate West Galveston Island from Galveston.

The road elevations on IH 45 just south of La Marque are down to five feet above MSL.

Five-foot tides will isolate Bolivar Peninsula from Galveston. Normally, the ferry ceases operation when tides reach 5 feet.

San Luis Pass bridge normally is closed when tides reach 3 feet, since the road on the Brazoria County side becomes flooded and impassable.

Texas City Area

Loop 197 between junctions of Highways 3 and 146 and Texas City Levee — 3 feet above MSL.

Texas Ave. or FM 1765 between 29th Street and Highway 146 — 6 feet MSL.

Highway 146 between Texas City and Dickinson Bayou, at Moses Lake — 5 feet MSL.

San Leon—Dickinson Area

FM 517 south, between the San Leon Area at the Chamber of commerce building and Highway 146—6 feet MSL.

Kemah — Seabrook and NASA Area

Highway 146 in Kemah between FM 2094 and Clear Creek — 6 feet MSL.

FM 2094 between Highway 146 and League City — 7 feet MSL.

NASA Road 1 between Highway 146 and Spacecraft Center —6 feet MSL.

Baytown Area

Lynchburg ferry crossing on Highway 134—4 feet MSL.

West Main in Baytown at Goose Creek—4 feet MSL.

By JACK STENGLER
Post Galveston Bureau

GALVESTON — All escape routes from Galveston Island, Bolivar Peninsula, Texas City and many other Galveston Bay areas would very likely be closed if tides during a hurricane reach five to seven feet.

Davis Benton, meteorologist in charge of the Galveston office of the National Weather Service, said this flooding is due to road elevations in the Galveston Bay area and other parts of the upper Texas coast reaching "very critical levels," due mostly to severe land subsidence.

"If a hurricane should strike this area during 1975, there is a real possibility that several thousand persons could be trapped by the rising tide waters if they fail to heed warnings," Benton said.

Evacuation stressed should major storm hit Bay

More than 300,000 persons li
Port O'Connor and High Islan
which would flood, he said in a r

Approximately 90 per cent of
who are killed in hurricanes ar
in tidal waters which rise 15
above normal.

Records show tides along
Texas coast, including Mata
Galveston bays reach 10 feet
years and as high as 15 feet ever

"With the severe land subside
Galveston Bay area over the pa
years, this situation has becc
more serious," Benton said.

He urged everyone in the fl
areas to be familiar with grou
tions and roads leading from the

More Realistic Building Code Could Reduce Hurricane Damage

Hurricanes, which have caused more damage than any other type of natural disaster in the United States, are a recurring threat for residents of the Texas coast. Although deaths from hurricanes have decreased in past years because of better warning systems, the dollar value of damage to property and homes soars with almost every hurricane because of the increased number of people living in coastal areas and the accompanying accelerated construction there.

"Most hurricane damage can be traced to inadequate building codes in the cities along the Texas coast," says Charles Hix, professor of architecture, building construction and civil engineering at Texas A&M University.

Recognizing this inadequacy, the Texas Legislature last session took some steps to help keep costly damage down and save lives and property in hurricane prone areas. The Texas Coastal and Marine Council and the Texas Engineering Extension Service of Texas A&M were made responsible for writing a more comprehensive model building code for use by Texas cities on a voluntary basis.

If Hurricane Strikes, 'Get Out', Benton Warn

By LYNN B. MILLER
News Staff Writer

In the event of a hurricane, persons who live along the Texas Gulf Coast should "get out," Davis Benton, chief meteorologist at the Galveston office of the National Weather Service, said at a hurricane preparedness seminar held Thursday.

"People used to think they could wait till the last minute to leave, but they no longer have that luxury," he said. "The name of the game this year is get out early if you plan to get out at all."

Since the Galveston area has not been struck by a major storm in 14 years, it is "overdue" for one this year, Benton said.

Familiarity with escape routes and land elevations may be the only means of survival, he added. Due to heavy land subsidence, most roads leading out of low areas are less than six feet above sea level. One portion of the Gulf Freeway, in the La Marque area, is only five feet above sea level.

An official hurricane tracking chart, produced by John Ferguson of American National Insurance Co. and Vandy An-

Apathy called danger in hurricane defense

NEDERLAND — Overcoming apathy from persons who had never been through a major hurricane was the main danger emergency workers were told to look out for Thursday at the annual pre-season hurricane conference sponsored by the Jefferson County Civil Defense.

The meeting drew about 90 persons from municipal and industrial police and fire departments, county officials and Civil Defense workers and was held at the Nederland city hall.

Paul Pettit, meteorologist in

Developing coast may be risky

AUSTIN (AP) — The director of the National Hurricane Center in Miami, Fla., says extensive development of the Texas coast could result in the deaths of several thousand persons from hurricanes.

Such a catastrophe, he said, could occur in the

Explanations sought for rapidly disappearing beach

By RAY WALLEY

SURFSIDE — The Army Corps of Engineers still does not have an explanation for the rapid erosion that has been occurring at Surfside Beach.

The Corps will continue to monitor the beach erosion, which has been estimated at 22-feet per year at some spots, Campbell said.

Discussion on beach replenishment plans to fight the sand erosion problem continues to be aired.

A few of the plans include dredging sand close to the shore and depositing it on the beach, dredging from the harbor channel and dredging from offshore.

Future plans for the Brazos Harbor Channel include widening the existing channel from a width of 560 feet to a total of 1,200 feet.

The widening of the channel would call for the removal of the existing north jetty, Surfside jetty, and moving it 600-feet north.

A proposal has been made that sand could be taken from the new channel and deposited on Surfside Beach.

Plans for the proposed channel widening have not included a starting or completion date.

George Kramig, heading a group of people interested in trying to save Surfside Beach, said he would like to see "two birds killed with one stone."

Kramig proposed that when the channel is widened that the dredged sand be placed on the beach — if it is the right quality for making a beach.

Not all ocean sand is good for making shoreline, Kramig explained.

Subsidence Has Doubled Hurricane Damage Prospects

A major hurricane striking the Houston-Galveston area could cause $1 billion in damage, a federal weather expert said.

That is about twice the financial loss attributed to Hurricane Carla, which battered Texas in 1961.

The expert, Davis Benton, said a significant factor in the projected increased damage from a major storm is land subsidence, which has added large areas of land susceptible to rising tides.

About 227 square miles of land in this area are now five feet lower than they were in 1961, said Benton.

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